ASSESSING COLOURS AS AN AID TO INCREASING THE DAYTIME CONSPICUITY OF CYCLISTS.

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ABSTRACT

Every year in New Zealand there are around 25 cyclist deaths and over 1000 injuries. The most serious type of accidents occur when cyclists are struck by motor vehicles. It has been found that a large number of these accidents are the result of low cyclist conspicuity. This thesis assesses various means of increasing the conspicuity of cyclists, with the aim of reducing the number of cycling accidents. It was considered that the best way to increase cyclist conspicuity was to use highly visible colours. Three fluorescent colours (lime/yellow, orange and pink) and three non-fluorescent colours (red, white and black) were assessed in a laboratory experiment. Forty subjects were shown slide presentations of the various target colours against backgrounds that differed in both colour and illumination. A distraction task was used as a means of presenting the targets in the subject's peripheral vision, where cyclists are usually first detected. Subjects were required to locate the targets in as short a time as was possible, so that the reaction time could be used as the measure of a target's conspicuity. It was found that the fluorescent colours were detected significantly faster than the non-fluorescent colours. Of the fluorescent colours, lime/yellow was the easiest to detect, followed by orange and then pink. It is concluded that fluorescent lime/yellow be used as the colour of choice by cyclists in order to increase their conspicuity, and thereby reduce the number of cyclist/motor vehicle collisions.

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INTRODUCTION

Every year in New Zealand there are on average 25 cyclist deaths and around 1080 injuries (Ministry of Transport, 1991). Although these figures represent only a small proportion of road accidents in New Zealand with around 5% of all reported casualties, it is considered that they are forming an increasing percentage of the overall traffic safety problem (Phipps, 1989).

It is also probable that the figures for cycle injuries are vastly under-estimated, especially for less serious accidents. Numerous studies have calculated the reporting rates of road accidents. In a hospital based examination of cyclist road accidents in England, Mills (1988) estimated that only 32% of the potentially reportable accidents had been reported to the police. In similar studies in New Zealand, estimates for the overall reporting rate vary from between 15% (P. Graham, personal communication, 2 April, 1993) to 40% (Atkinson & Hurst, 1983). What is clear is that the number of accidents involving cyclists is far larger than what the official figures would indicate. Along with this, it has been estimated that for every injury accident, there are 1000 near misses involving emergency braking or swerving (Spicer, 1973, cited in Hills, 1980).

Accidents involving cyclists tend to be more frequent per distance travelled, and more serious than those involving other modes of transport. In a study of traffic safety for cyclists in Denmark, Hansen and Jorgensen (1988) estimated that cyclists have four to five times as many accidents per kilometre as motor vehicle users. In a study of New Zealand accidents, Atkinson and Hurst (1984) found that cyclists in urban areas were twice as likely as motorcyclists and 55 times more likely than car drivers to suffer injury.

The most serious cycling accidents are those that involve collisions between a cyclist and a motor vehicle. This is due to the higher impact speeds and larger masses involved. Such accidents often result in serious injuries or fatalities. Atkinson and Hurst found that 20% of adult cyclist injury accidents result from a collision with a moving motor vehicle. However, these accidents result in 85% of cyclist fatalities. It was estimated by Cross and Fisher (1977) that for every cycle/motor-vehicle accident, the cyclist would suffer on average 1.4 days in hospital, 1.4 days in bed at home, 7.4 missed days at work or school, and 23.6 days in pain or discomfort. Analysis of the New Zealand statistics shows that in the 1990 year, 378 cyclists were hospitalised, for an average of 10 days (Ministry of Transport, 1991). Along with the immense physical and emotional costs of such accidents there are also severe financial costs. Figures from the Accident Compensation Corporation (1991) show that for the 1989/90 year, 1,248 claims for compensation were made, with more than $1.14m paid out to cyclists for injuries. In addition to the cost of injuries there is also the cost of damage to the vehicles involved. Cross and Fisher (1977) suggest that although the damage to a motor vehicle was usually small when colliding with a bicycle, quite often the collision causes the motor vehicle to collide with another vehicle or a fixed object.

Cycle accidents are especially a problem in a city such as Christchurch where due to the flat terrain and mild climate, there are a large number of cyclists (Atkinson & Hurst, 1984). Ferguson and Blampied (1991) further suggest that the cycling hazard is increased in Christchurch due to its southern latitude. In winter, with the earlier sunsets, visibility is poor from the late afternoon onwards, a time that coincides with peak traffic.

There are a large number of causes of collisions between cyclists and motor vehicles. Cross and Fisher (1977) suggest that there is no single causal factor that is sufficient in itself to produce an accident. They make an assumption of multiple causality in cycling accidents. Although a single factor may have been necessary for a particular accident to occur, such as a driver being intoxicated, it does not follow that in every case where a driver is intoxicated an accident will occur. The cause of an accident is some combination of factors that when occurring together result in an accident. Having said this, it is possible to identify factors that often have some causal influence on motor vehicle/cyclist collisions. This identification often comes from the analysis of road accident reports.

One factor that has often been identified as a cause of cyclist collisions is cyclist conspicuity. A detailed definition of conspicuity will follow, but for the time being conspicuity could be thought of as the visibility of the cyclist as perceived by the driver.

Mills (1988) conducted a study of cyclist accidents in the UK by administering questionnaires to 776 cyclists who attended hospital after having accidents. In collision type accidents, conspicuity was assessed to be a contributing factor in 20% of cases. In a comprehensive study in the United States of motor vehicle/cyclist collisions, Cross and Fisher (1977) identified the major problem types or causes of accidents. They examined 166 fatal accidents, and 753 non-fatal accidents. In total they identified 36 unique problem types, some of which were attributable to the cyclist, and some of which were the fault of the motor vehicle driver. Of these 36 problem types, seven accounted for around half of all accidents. In all but one of these seven most frequently occurring problem types, conspicuity was mentioned as either a direct or indirect cause of accidents.

On closer analysis of all 36 problem types it could be seen that conspicuity had a major part to play in many of the accidents. Conspicuity played a direct role in 12% of all fatal accidents and 36.7% of all non-fatal accidents. An example of what is meant by a direct role can be seen in Cross and Fisher's (1977) 'Type 23' accidents. This is where a motorist makes an unexpected turn in front of a cyclist apparently not having seen them. Conspicuity could also be said to have an indirect link in 27.1% of all fatal accidents, and 30.9% of all non-fatal accidents. An example of what is meant by an indirect link can be seen in accidents where cyclists ride out from drive-ways, alley-ways and from controlled intersections into the path of an oncoming car. Obviously such accidents are the fault of the cyclist, but it is possible that a number of such accidents could have been avoided if the cyclist had been seen earlier (or more easily).

As Cross and Fisher (1977) mention, some problem types are more likely to occur in some types of areas than others. This is particularly important when comparing two countries which have different road rules. Atkinson and Hurst (1983) conducted a study of the New Zealand situation based on the Cross and Fisher (1977) report. They found a number of differences in the causes of accidents. A number of accidents that were directly attributable to conspicuity in the United States did not happen in New Zealand due to different driving rules or conditions. Even so there were still a number of situations where conspicuity directly contributed to collisions, and the case still stands that conspicuity will certainly have an indirect influence on accidents.

Phipps (1989) also made a study of cyclist accidents in New Zealand between 1980 and 1987. Although it is hard to tell from this data specific causes of a collision it is possible to identify cases where conspicuity may have played a part. A failure by the motor vehicle driver to give way to cyclists was the most frequent cause of accidents, at 22.7% of all cyclist/motor vehicle collisions. This was especially the case with cars turning that failed to give way to cyclists who were travelling straight, and also the failure to give way to cyclists at give-way signs. It appears that in both these cases it is possible conspicuity could play a major role. An alternative possibility of course is that motorists failed to recognise the need to give way. It is difficult to tell from this data which situation is the most likely, but it is probable that both play a role.

A more local study was made by the Christchurch Cycle Safety Committee (1991) into cycle use and collisions. This group distributed questionnaires to both adult and young cyclists. Nearly 1400 questionnaires were completed by adult cyclists. One group of questions asked whether the respondents had been in a collision during their cycling careers. Fifty seven percent of adults reported that they had, while eighteen percent of all adults reported that they had been in a serious accident. Serious accidents were defined as those that required the respondent to see a doctor or visit a hospital. Respondents were required to indicate what they thought was the major contributing factor in the accident. This type of question could be considered to be biased, as it is unlikely that the respondent would indicate that they were at fault. Even so, such results do provide a good indication of accident causation.

Adult respondents indicated that the category 'Not seen in time' was the biggest contributing factor to cycling collisions. This category accounted for 43% of all serious collisions, and 38% of all non serious accidents. It was also found that failure of a motorist to be aware of cyclists was of major concern to adult cyclists. In a question on the concerns of cyclists, it was found that 14% were worried about cyclist vulnerability, including fear of not being seen by a motorist.

School children were also given questionnaires. Most respondents were between the ages of 11 and 17 in this part of the study, and there were 3497 completed forms. Over 50% of the children reported that they had been in a collision. Within the previous year, 11% of respondents reported that they had been in at least one serious collision, while 31% had been in a minor collision. 'Not seen in time' was considered to be the third most important contributing factor in accidents. It was felt that this category contributed to 22% of all serious accidents, and 16% of minor accidents. Again, respondents were asked what their major concerns were when cycling. Nearly a quarter of this group reported that a feeling of vulnerability , including the fear of not being seen by a motorist, was the greatest concern they had.

In summary, various studies have indicated that cyclist conspicuity is a major contributing factor in cyclist/motor vehicle collisions. Also a fear of not being seen by motorists is common amongst cyclists. It is concluded that by increasing the conspicuity of cyclists it may be possible to decrease the number of cyclist/motor vehicle collisions.

The chances of a cyclist having an accident are greatest at night. Noordzij (1976) suggests that the chances of cyclists having an accident at this time are four times greater than during the day. Even so, the largest number of accidents occur during the day. In New Zealand, 85% of all accidents occur during daylight (Phipps, 1989). For this reason, and as there are a number of measures which have already been identified as increasing conspicuity at night (see e.g., Noordzij, 1976), this study will concentrate on cycling accidents during the daytime.

It is the aim of this study to find an aid to conspicuity that will increase cyclist daytime conspicuity. Before this is attempted it is important to examine exactly what conspicuity is, and how it may be increased. For this it is necessary to examine previous research in this area.

Conspicuity

Conspicuity was briefly defined earlier as the visibility of an object (particularly the cyclist) as perceived by an observer (the driver). The terms conspicuity and visibility are often used interchangeably, but there are differences between their definitions.

Visibility could be best described as the capability of an object to indicate its presence to an observer in conditions where there are no distractions, and the observer is able to concentrate completely on the task of observing. It is also assumed that there are no physical barriers to the detection of the object. Conspicuity differs in that it considers various viewing conditions, and allows completely for all sources of distraction. This includes cognitive factors, such as viewer expectations, as well as more physical factors such as object visibility. It includes whether the target object stands out more strongly than those objects that surround it. For a more thorough discussion of these differences see Williams (1976).

It is important to note that although the two terms differ in definition, the factors that are important for increasing visibility are not necessarily different to those that influence conspicuity. The difference does indicate the need for an alternative method of experimentation for research into conspicuity than may have been used in visibility, such as introducing sources of distraction.

Forbes (1939, cited in Dahlstedt, 1986) was perhaps the first to realise this distinction between visibility and conspicuity, or what was termed 'attention value' in the road traffic setting. The concept of attention was introduced, and it was pointed out that something stronger than visibility was needed in seeing road signs especially if these signs were unexpected, or the observer was not particularly interested in them.

Many studies have been conducted in the area of conspicuity, and many definitions have been used. Often conspicuity has been incorrectly confused with visibility or definitions equating to it. For example, Beith, Sanders and Peay (1982) define conspicuity as the "... ease with which a person or object can be seen. It is dependant, among other things, upon the luminance and contrast of the target" (p. 727). More recently, Wulf, Hancock and Rahimi (1989a) defined it as "... the ability of an object to attract attention and to be easily located, due to its physical properties" (p. 157).

Various other definitions have been used and many of these have had an influence on the methodology employed by the researcher. Engel (1971, 1974, 1977) sparked a line of methodological inquiry by defining the 'conspicuity area'. This refers to the retinal field in which the object is able to be noticed with a single eye pause when the subject has no foreknowledge of its location. The larger this conspicuity area, the greater the conspicuity of the object. This definition also regarded conspicuity as an object factor, and paid little attention to observer characteristics.

Cole and Jenkins (1980) later expanded on this definition considering that a conspicuous object was one that could be seen with certainty within a short observation time regardless of the location of the target with respect to the line of sight. They defined conspicuity as the largest angle between the target and the line of sight at which the target could still be seen at a glance. This definition, by limiting presentation to a glance prevents subjects from making a visual search. This definition is also interesting as it refers to the use of peripheral vision as an aspect of conspicuity. Cross and Fisher (1977) also made use of this peripheral component in their definition by saying that conspicuity is the attention getting quality of the object, particularly when the object appeared in the viewer's peripheral field of view. This point will be raised again at a later stage.

Hughes and Cole (1984) further developed Engel's (1971) definition by including the state of arousal and expectation of the observer, or some of the cognitive factors involved in conspicuity. They also make the point that alternative methods, such as the use of search time may also be appropriate for research in this field, especially if the targets are relatively inconspicuous.

Boersema and Zwaga (1985), used a paradigm similar to that in Hughes and Cole's (1980) study, and defined conspicuity as the probability that an object will be noticed by an observer within a fixed time. Later they changed this definition to the time an observer needs to notice a target (Boersema & Zwaga, 1988; Boersema, Zwaga & Adams, 1989), although they use both definitions interchangeably.

Theeuwes (1991) recognised the lack of consideration given to cognitive factors in earlier definitions of conspicuity. Instead an eclectic model was proposed that combines both exogenous factors, or the perceptual prominence of a target, with endogenous factors, or those cognitive factors such as expectations.

Mace, Perchonock and Pollack (1982) also make use of the cognitive aspect of conspicuity in their definition. They state that conspicuity is not an observable characteristic of an object, but rather is a construct which relates measures of perceptual performance with measures of background, motivation, and the uncertainty of the driver.

In summary, conspicuity can be defined as the capability of an object (in this case specifically a cyclist) to be noticed by an observer. This noticeability will depend both on the physical properties of the object and its surround, and on the properties of the observer. Conspicuity can only be understood in terms of the relation between these two classes of variables. What follows is a more detailed examination of these two types of influence.

Factors Influencing Conspicuity

Many factors have been identified that may be considered to have an influence on the conspicuity of an object. Research in this area has occurred in both experimental and applied settings.

Object characteristics.

A number of object or target characteristics have been identified as having an influence on conspicuity. These include the size of the object, its shape, motion, its internal contrast, background complexity, the similarity with the background, and the luminance and colour contrast with the background.

Size. A number of investigators have examined the effect of size on the conspicuity of an object (e.g., Beith, Sanders & Peay, 1982; Fulton, Kirkby & Stroud, 1980; Hughes & Cole, 1984; Seigel & Federman, 1965; Solomon, 1990; Stroud, Kirkby & Fulton, 1980; Thomson, 1980; Williams, 1976; Woltman & Austin, 1974). As expected, with an increase in the size of the object, there is an increase in its conspicuity. Allen (1970, cited in Thomson, 1980) identified a critical size needed for an object to be conspicuous. It was suggested that the object should subtend a visual angle of more than 0.58 milli-radians (0.033 deg) to be conspicuous.

Seigel and Federman (1965) also found that with an increase in size there was an increase in conspicuity. However, this only occurred up to a point. There appears to be some size threshold beyond which an increase in size has no effect. They identified this threshold as being at around 20 to 25 minutes of visual angle (0.3 - 0.4 degrees).

Evidence also comes from field work on the effect of target size. Hughes and Cole (1984) found that when using circular target disks, larger disks were seen more easily in the road environment. Fulton, Kirkby and Stroud (1980) found that the larger the area of the body covered by fluorescent material, the greater the conspicuity of the person. In a similar study, Michon, Eernst and Koutstaal (1969) found that a band of approximately 30 cm width was large enough to increase the conspicuity of a person.

Shape. Another factor that has been identified as having an influence on conspicuity is the target shape. For example, Seigal and Federman (1965) compared rectangular with square shaped targets while holding the area of the stimuli constant. They found that square shaped stimuli were more effectively detected than those of rectangular shape. Yi (1988) compared the conspicuity of two different shapes in an examination of road signs. It was found that diamond shaped road signs were detected faster than rectangular ones. Yi suggested that this may be because the lines of the background objects (e.g., roads and buildings) were of vertical and horizontal orientation, as were the lines of the rectangular targets. Target shape is probably related to background similarity (as will be examined shortly).

Motion. Solomon (1974) proposes that motion also has an influence on conspicuity. It is suggested from this examination of fire-fighters that reflective material should be placed on the hands and feet where motion is maximised. Reinhardt-Rutland (1991) also discussed target motion as a factor in conspicuity with reference to when it is dark. It is suggested that one reason for the large number of road accidents at night, even when the object is illuminated, is that there is no relative motion when the environment around the wearer is not also alight. They support this by pointing out that street lighting, which affects the conspicuity of both the person and the environment, is effective in accident reduction. Finally, Rumar (1980) in a subjective study, asserts that motion is the primary cause of detection of oncoming vehicles in 8%

of cases.

Internal contrast. Internal contrast (i.e., an abrupt change in luminance within an object) is often assumed to be effective in increasing the conspicuity of an object (e.g., Cole & Hughes, 1988; Hughes & Cole, 1984; Seigal & Federman, 1965). A number of studies have found that this is not the case. Bradford (1992; Bradford, Isler, Kirk & Parker, 1992) in a laboratory based experiment found that in the design of high visibility shirts, those with high internal contrasts were not seen significantly faster than those without. Michon, Eernst and Koustaal (1969) reported similar results in their field investigation of safety clothing.

Background complexity. Interactions between the object and its background have been identified as playing perhaps the most important role in conspicuity. One such factor is the complexity of the background. In an experimental study, Jenkins and Cole (1982) found that with an increase in the background density (i.e., the number of objects in the background) there was a subsequent decrease in the conspicuity of a target. Cole and Jenkins (1984) found similar results in their experimental study. Boersema and Zwaga (1985, 1988; Boersema, Zwaga & Adams, 1989) found in an applied setting that an increase in background complexity resulted in lower conspicuity. They found that subjects were slower to locate routing information signs when the number of advertisements in the same scene was increased.

Background similarity. Similarity with the background has also been identified as a factor in conspicuity. For example, Cole and Jenkins (1984) found that with a high variability in the sizes of background circles, a greater size difference was required in the target circle for it to be conspicuous.

Luminance contrast. The factor that is said to have the greatest impact on the conspicuity of an object is the luminance contrast between the target and its background. Numerous studies have reported this aspect of conspicuity (e.g., Beith, Sanders & Peay, 1982; Cole & Hughes, 1988; Hughes & Cole, 1984; Jenkins & Cole, 1982; Michon, Eernst & Koutstaal, 1969; Rumar, 1980; Thomson, 1980; Williams, 1976; Yi, 1988).

In an examination of vehicle detection, Rumar (1980) found that brightness contrast was thought to be the primary cause for the detection of an oncoming vehicle 52% of the time (as judged by subjects). A number of formulas have been developed to express the luminance contrast between the target and its background (Sekuler & Blake, 1985). These usually divide the luminance of the target by the luminance of the background. It is suggested that the higher the value of the contrast ratio, the greater the conspicuity of the target. Experimental studies (e.g., Jenkins & Cole, 1982) have shown this to be true, and indicate that luminance contrast is a good predictor of target conspicuity.

Colour contrast. Similar to luminance contrast, and most probably related is the colour contrast between the target and the background. Hughes and Cole (1984) suggest that if by chance there is little luminance contrast between a target and its background, the colour contrast may still enable the target to be seen.

In an experimental study, Carter and Carter (1981) found that conspicuity was maximised when there was the greatest difference between target and background colour. However, this experiment did not hold the luminance of the colours tested constant, so it is difficult to tell how important each of these factors are. Barbur and Forsyth (1988) did study colour contrast while holding luminance constant. They found that over a number of different colours, search time increased when the background and targets were close to equiluminance, meaning they were less conspicuous. Even so, the equiluminant colours were a good source of conspicuity.

Rumar (1980) suggests that luminance contrast is more important than colour contrast. As mentioned above, brightness contrast was the primary source of detection for oncoming cars in 52% of cases, whereas it was found that colour contrast was the primary cause in only 16% of cases. As Michon et al. (1969) suggest, it is probable that in normal viewing situations we use both colour and luminance contrast in the detection of objects.

Observer characteristics.

As mentioned, it was probably Forbes (1939, cited in Dahlstedt, 1986) who first introduced the concept of attention to conspicuity. However, it was not until Engel (1976, cited in Wulf, Hancock & Rahimi, 1989a) introduced the notion of sensory versus cognitive conspicuity that experimental work began in this area. Sensory conspicuity refers to those object characteristics mentioned above, whereas cognitive conspicuity depends on the interests and experiences of the observer. One aspect of cognitive conspicuity concerns the expectancy of the observer, and a number of authors have examined this concept (e.g., Fulton, Kirkby & Stroud, 1980; Hills, 1980; Thomson, 1980; 1982; Wulf, Hancock & Rahimi, 1989a).

Fulton, Kirkby and Stroud (1980) discuss the idea of an 'expectancy phenomenon'. Due to the infrequency of some targets (e.g., cyclists in the traffic situation) we come to not expect the presence of such targets. Wulf, Hancock and Rahimi (1989b), in examining motorcyclist accidents, suggest that due to the low event rate of motorcycles (1 per 175 vehicles in traffic), motorists are not conditioned to detect the presence of a motorcycle when they do appear. For this reason, the motorist may look directly at the motorcyclist and not see them. Brooks (1988) suggests that to overcome this expectancy problem, observers need to be educated about the presence of low event rate targets. There is some evidence for this (e.g., Wulf, Hancock & Rahimi, 1989a), with an under-involvement of those motorists familiar with motorcycles (in particular those motorists who also held a motorcycle license) in collisions with motorcycles.

Cole and Hughes (1984,1988; Hughes & Cole, 1984,1986) expanded on Engel's earlier definitions of sensory and cognitive conspicuity by developing the concepts of attention versus search conspicuity. 'Attention conspicuity' refers to the ability of an object to attract the attention of an observer even when that observer is not expecting the occurrence of that object. This is in contrast with 'search conspicuity', where the attention of the observer is directed to find a specific target, or where the observer is actively searching for needed visual information.

It was found that those subjects who were given instructions to search for specific targets (i.e., search conspicuity) reported the presence of these targets three times more often than did those who were not given such instructions (i.e., attention conspicuity). This indicates that targets were more conspicuous to those in the search conspicuity condition, even though the physical properties of the targets had not altered. One factor that has not been identified in this type of research is whether there is any difference in the order of detection for different treatments (e.g., the order in which different colours are detected) between these two search strategies.

Rumar (1990) takes an evolutionary approach in analysing cognitive factors in the traffic situation. It is suggested that humans are not protected by evolutionary adaptation for driving in an artificial environment such as we see on modern roads. The search patterns that we use for detection of other vehicles are not automatic and skill based as they are in the natural environment, but rather are controlled and rule based. This is what leads to cognitive errors in the driving situation, such as a failure to scan for certain types of targets. Related to this is the fact that we have a limited attention capacity (e.g., Thomson, 1980). In cognitively demanding situations such as those that occur at intersections, some important visual information may not be acquired. It is suggested that this results in the driver not detecting certain types of vehicles.

It could be concluded that there are a number of object characteristics that influence the conspicuity of a target. This conspicuity may however be reduced by cognitive components of the observer. This has been a major criticism of research into conspicuity (e.g., Theeuwes, 1991; Brooks, 1988). It is suggested that no matter how much attention is paid to increasing the conspicuity of an object, this may always be reduced by cognitive aspects of the observer. It is suggested by critics (e.g., Brooks, 1988) that training (such as increasing the driver's awareness of cyclists) is the only way to increase the conspicuity of objects. From the above evidence it is probable that such training will result in greater detection of inconspicuous objects, but it is debatable as to whether this is the only way to increase conspicuity.

It appears that for an object to be conspicuous it must exert some cognitive control over the observer by automatically attracting attention, and that the object must have extraordinary properties to exert such control. Every day experience would tell us that such conspicuous targets do exist. For example, the flashing lights of a fire engine, or a flash of lightning are hard to miss even if the observer is fully engaged in another activity. Even critics of the conspicuity approach suggest that targets with such properties do exist. Theeuwes (1991) states that "some stimulus features are capable of exogenously pulling attention to their location independent of the state of the observer" (p. 59). This statement was supported with an experiment which showed that attention was automatically captured by stimuli containing an abrupt change in luminance. Further support for this assertion comes from research in the ecological approach to perception. Michaels and Carello (1981) suggest that it is not the case that we must be searching for something in order to detect it. They state that much of exploration and attention is controlled by intention, but that it is also true that they are at the beck and call of the environment. Some portions of the array are more structured than others, and it is those portions that will arouse attention. Shaw and McIntyre (1974) have identified such portions of the array as having higher 'attensity'. Areas of high attensity are more likely to be noticed, while those with low attensity may go unnoticed.

It would seem that in order to increase conspicuity we should investigate targets with extremely high visibility and also attempt to increase the cognitive awareness of road users through training. However, it has been suggested that it would be comparatively inefficient to try to educate road users on the cognitive aspects of driving, such as taking greater notice of low event rate objects like cyclists (e.g., Rumar, 1990). It is not suggested that such areas of enquiry should be abandoned as the two options are complimentary. Rather, it is likely that the most beneficial area for initial research lies in increasing conspicuity by improving target characteristics. Rumar (1990) suggests that measures involving the enhancement of the target have proved to be efficient in improving conspicuity in both experimental studies and in accident analysis. It was further suggested that improving target conspicuity will decrease both cognitive and perceptual road traffic detection errors.

Although it is recognised that there are cognitive components involved in the conspicuity of objects, this investigation will concentrate on the object characteristics of the target as a way to increase cyclist conspicuity. Specifically, the contrast between the object and its background will be examined in this study. This is because it has been shown to be the most important object characteristic in conspicuity, and secondly it is the easiest feature to change in the cycling situation. Other factors such as cyclist size, shape and motion, and the type of background that they are seen against would be extremely hard or impossible to change.

Conspicuity in the Applied Setting

The results of research into conspicuity have been used in a number of applied settings, not all of which relate to the road traffic situation. Examining such studies is useful both for the results they provide and the methods that are adopted.

Boersema and Zwaga (1985, 1988; Boersema, Zwaga & Adams, 1989) are among a number of researchers who have examined the conspicuity of routing information signs. They determined that with an increase in the number and size of poster advertisements in the vicinity of routing information, the conspicuity of such signs decreased (i.e., there was an effect for background complexity).

Siegel and Federman (1965) developed a paint scheme for aircraft that was thought to give maximum conspicuity. Through a number of experimental and field studies, they concluded that the greatest conspicuity was found with a large square shaped fluorescent red-orange area, which had a high contrast with a second colour. They also discuss a number of studies that have examined the conspicuity of objects at sea.

Other researchers have examined the conspicuity of objects under water. Kinney, Luria and Weitzman (1969) evaluated a number of colours for use under water in a variety of conditions. They found that fluorescent colours were seen the best with both incandescent and mercury light sources (also see Allan, Brennan & Richardson, 1989).

Michon, Eernst and Koutstaal (1969) assessed a number of fluorescent and non-fluorescent colours for use as safety clothing for people who work on or near the road. They measured various colours against grey and blue backgrounds. It was found that fluorescent orange was the best colour under these background conditions.

Beith, Sanders and Peay (1982) conducted an investigation into the most effective way to increase the conspicuity of coal miners. The underground mining environment is usually dark, so they assessed the effectiveness of various configurations of retroreflective materials. They used a simulation to test the effectiveness of these configurations for various body postures commonly found in the mining situation, and for their effectiveness in the peripheral vision of the observer. It was found that larger target coverage was required at the extremities of the peripheral field (at 45 deg) than when the target was closer to the line of sight (at 10 or 25 deg).

Solomon (1990) discusses the conspicuity of fire engines. It is suggested that red is the colour for fire appliances due to tradition and that there is a real reluctance to change. This is even though there is strong support from the literature to suggest that red is a weak colour to detect, especially at night and in peripheral vision. It is concluded that fluorescent lime/yellow should be adopted as it has been found to be a distinctive, highly visible safety colour. This is supported by a study that showed that regions which had lime/yellow fire appliances had half the number of intersection accidents as those using red appliances. In a similar study (Solomon, 1974) it was also suggested that this colour should be adopted by fire fighters in the protective clothing they wear.

Shuman (1991) supports Solomon's suggestion, and considers that not only should fire appliances and fire fighters be coloured lime/yellow, but also cars and trucks. Mercedes-Benz has developed a 1-to-100 safety scale for colours after conducting visibility tests. On that scale, black rates 5%, while Arctic white rates 73%. In comparison, red rates only 38%. Although much research has been conducted on the most conspicuous colours for cars, there is large consumer resistance to using highly conspicuous colours due to aesthetic concerns. It is suggested by Shuman

(1991) that lighter and brighter colours are currently popular, more because of fashion trends than because of concerns for safety.

Zlotnicki, Hutchinson and Kendall (1980) also suggest the need for greater conspicuity for trucks. Even though trucks are much larger than cars, they also present a problem as they are often dark coloured. Their study identifies a number of situations in which trucks were not seen due to low conspicuity. This finding may provide support for Seigel and Federman's (1965) discovery that there is a critical target size, after which conspicuity is not increased.

An analysis of safety clothing for forestry workers was conducted by Bradford (1992; Bradford, Isler, Kirk & Parker, 1992). It was found for these workers, who operate mainly in a green environment, that fluorescent lime/yellow was the most conspicuous colour. It was later discovered that the use of these colours in the applied setting had been effective in the reduction of accidents where loggers were not seen (R. Parker, personal communication, 15 February, 1994) although it is too early at this stage to quantify this.

A large literature exists on the conspicuity of road signs (e.g., Kline, Ghali, Kline & Brown, 1990; Macdonald & Hoffman, 1991; Yi, 1988). For example, Yi (1988) found that with greater contrast between the road sign and its background, the more conspicuous it is. It is suggested that this information is of use to traffic engineers when positioning road signs.

Tenkink and Walraven (1988) have conducted research into conspicuity of the flashing warning lights at rail crossings. They found that conspicuity could be increased by making a threefold increase in the luminance of warning lights, by using a larger background screen, or by creating a more abrupt transition of the lights.

Very little research has been conducted specifically on the conspicuity of cyclists. Watts (1980) conducted an experiment that evaluated various aids for cyclists. The effectiveness of a fluorescent orange pennant, a black panel with fluorescent yellow stripes, a fluorescent orange helmet, waistcoat and jacket, a fluorescent yellow waistcoat, a non fluorescent yellow jacket, and a dark blue jacket were assessed. These aids were tested against both dark and light background conditions. It was found that the fluorescent yellow jacket and the fluorescent orange helmet were the most conspicuous aids, especially against the dark background.

An area with close similarity to the conspicuity of cyclists is research that has been conducted into the conspicuity of motorcyclists. There is an extensive literature on this topic (e.g., Dahlstedt, 1986; Donne & Fulton, 1985; Foldvary, 1973; Fulton, Kirkby & Stroud, 1980; Olson, 1989; Olson, Halstead-Nussloch & Sivak, 1979, 1981; Ramsey & Brinkley, 1977; Rumar, 1980; Stroud, Kirkby & Fulton, 1980; Thomson, 1980, 1982; Vaughan, 1976; Watts, 1980; Williams, 1976; Williams & Hoffman, 1977; Woltman & Austin, 1974; Wulf, Hancock & Rahimi, 1989a, 1989b). The results of such studies are directly applicable to the cycling situation. There are a number of minor differences, such as the larger size of motorcycles, the faster speeds at which they travel, and the different road position which each uses. It is possible that the effect of the smaller size of the cyclist is negated by the speed at which cyclists travel. Cyclists do not have to be seen at such a great distance due to their slower speeds, meaning that at the point at which they must be detected in order to avoid an accident they are comparatively larger than motorcycles.

Dahlstedt (1986) suggests that the extensive enquiry into the conspicuity of motorcyclists was begun after the release in the US in 1969 of a large scale accident analysis which showed there were a great number of collisions between motorcycles and other vehicles. Most of these studies conclude that conspicuity seemed to be a major contributing factor in many of these accidents. As is the case with cyclists, it is often claimed that the car driver was unable to see the motor-cyclist.

A number of countermeasures have been developed to try to increase the conspicuity of motorcyclists. The vast majority of these involve increasing the contrast between the motorcyclist and their background. Much of the early research concluded that the use of bright colours, particularly fluorescent colours, was effective in increasing the conspicuity of motorcyclists. Fluorescent pigments work by re-admitting light that is normally absorbed as heat. This emitted light is the same wavelength as the hue that is being reflected by the pigments. This produces colours that appear extraordinarily bright to the observer. Typically, these studies assess one fluorescent colour (the vast majority test fluorescent orange) in various positions on the rider or motorcycle itself. A number of researchers have found that positioning these colours on the rider has a greater effect than placing them on the motorcycle (Dahlstedt, 1986; Olson et al., 1979), possibly due to the height of the rider. Some authors suggest that only a small area of fluorescent colouring is necessary, with a few studies showing that a fluorescent helmet is enough to significantly increase conspicuity (e.g., Fulton et al., 1980; Stroud et al., 1980).

Research into conspicuous colours was later abandoned when it was discovered that in most situations the use of high beam headlights on motorcycles was as effective, or more effective than using bright colours. It was also thought at the time that lighting was more effective, as fluorescent colours were liable to fade with time. However, the capability to use high beam headlights on cycles in the daytime does not exist. Also, with recent improvements in technology the length of time that fluorescent colours are able to last without fading has increased (R. Parker, personal communication, 15 February, 1994).

Peripheral Detection Of Targets

Studies on visual conspicuity typically focus on the peripheral vision of the observer. This is because detection usually takes place in the periphery of the retina (e.g., Wulf et al., 1989a). Based on the information available in peripheral vision, the observer decides where next to fixate for more thorough analysis via the fovea (Phillips, 1979; Hills, 1980). Properties that attract attention in the periphery of the visual field are generally the same as those mentioned above. However, it is likely that luminance contrast plays an even greater role in the peripheral detection of targets (e.g., Barbur & Forsyth, 1988; Beith et al., 1982). This is because the periphery is not well adapted to detect aspects such as colour, shape or many of the other factors mentioned as impacting on conspicuity. Also, the further into the periphery that a target is presented, the harder that target is to see (e.g., Siegel & Federman, 1965; Beith et al., 1982). It is therefore important in this study that the targets tested be presented in the peripheral region of the subject's vision.

Methodologies Used In The Examination Of Conspicuity

Many methods have been used in assessing those objects with high conspicuity, although most of these fit into a small number of broad categories.

Estimation. Several researchers have made use of subjective measures of conspicuity. Dahlstedt (1986) used the technique of magnitude estimation in examining conspicuity. A car was used as a reference point against which various treatments were compared. Ramsey and Brinkley (1977) used a similar method as part of their investigation. Subjects were asked to give a numerical rating to each of four stimuli, with the reference point being based on a score given to that subject's perceived most conspicuous stimuli.

The advantages of using subjective techniques are that viewing can take place under relatively realistic conditions, and that such a technique is quick and easy. However, there are also severe disadvantages with this technique, the greatest being that it is open to possible sources of bias. For example, subjects may use criteria other than target conspicuity in choosing the best target. It has also been shown (e.g., Rumar, 1980) that what people rate as being highly conspicuous does not necessarily correspond to what is conspicuous in the applied situation.

Recall A second technique that has been commonly used is subject recall (e.g., Ramsey & Brinkley, 1977; Stroud et al., 1980). This method typically involves positioning the target (usually a motorcycle) in a side street, and then interviewing a pedestrian or motorist as to whether they saw the target. The proportion of those who recalled the presence of the target is used as the measure of conspicuity.

The benefit of this method is that those who are interviewed are unaware they are in a test situation, meaning that viewing the object is similar to the real world situation. However, the validity of such a technique is doubtful for a number of reasons. It is possible that recall is influenced by novelty factors of the stimulus or by memory capabilities (Wulf et al., 1989a; Thomson, 1982; Watts, 1980). Also, the questions asked of participants are often leading. For example, in the study by Stroud et al. (1980) pedestrians were simply asked whether or not they had noticed a motorcycle in the side street. They did not include any catch trials to determine whether the respondents' reports (i.e., the detection or non-detection of the motorcycle) were accurate.

Critical distance to detection. A number of researchers have used the distance at which a target is detected as the measure of conspicuity. A variation on this is to use the time to detection as the measurement criteria. Watts (1980) had subjects sit in a test vehicle. While looking for the appearance of a cyclist, they were required to engage in a distraction task. A cyclist travelled towards the test vehicle at 16 km/h. Upon the detection of the target, the subject was required to make a response, whereby the distance from the test vehicle of the cyclist was determined. Michon et al. (1969) conducted a similar study in the laboratory situation using scaled models.

The disadvantages of this technique are that subjects are usually expecting the target, so this does not fully approximate the real-world situation. Also, it is hard to keep such experiments controlled, as factors such as travelling speed are difficult to keep constant. Finally, such experiments are time consuming as each trial may take some time, and a large number of trials are needed to provide a statistically significant result.

Gap acceptance. A fourth methodology that has been commonly used is gap acceptance. A gap is created in traffic between a lead vehicle and the test vehicle (usually a motorcycle). The gap size required by subjects to complete a merging manoeuvre may be used as the measure of conspicuity for the various treatments, or alternatively, acceptance or non-acceptance of gaps is recorded for different gap sizes. Often it is the case that the drivers of both the lead vehicle and the subject vehicle are part of the normal traffic flow and do not know that they are part of an experiment (e.g., Olson et al., 1981).

The gap acceptance technique has the advantage again that subjects do not know they are involved in an experiment. However, this methodology has been criticised on a number of counts. Fulton et al. (1980) suggest that a large number of trials are needed, so this technique is not an efficient way to collect data. Thomson (1982) suggests that gap acceptance does not directly measure conspicuity, but rather explores the decision processes of the subject. Also, little difference has been found in gap acceptance behaviour when the type of following vehicle is altered. This would indicate that no matter what conspicuity aids are assessed, there will be no resultant change in gap acceptance behaviour. This assertion is supported by a number of researchers who have found no significant differences between conspicuity treatments when using this technique even though follow-up studies indicate that there is (e.g., Stroud et al., 1980).

Colour contrast. Carter and Carter (1981) developed an experimental technique to quantitatively assess conspicuity. They suggest that conspicuity can be evaluated in the laboratory by using a target that has maximal colour difference to its background. The benefit of such a method is that it is quick and economical. However, it does not consider the cognitive state of the observer , excluding factors like sources of distraction. An even greater problem is that this technique only considers one background colour. In the real-world situation there is seldom a single uniform colour, but rather a variety of different colours and textures.

Self report. Hughes and Cole (1984; Cole & Hughes, 1984) use a method in their analysis of road traffic control devices that required the subject's to report everything that they saw. Subjects drove around a 22 km route, and were required to report verbally all the objects that attracted their attention (in a second condition, subjects were required to report all traffic signs that attracted their attention). The frequency with which an object was reported was an indication of its conspicuity.

Such a method could be considered inappropriate as it is impossible to report all objects that are seen. Also, especially in the case of road traffic signs, information may be gathered at an automatic level, and so the subject may be unaware that they had seen a sign. This is supported by the fact that in Hughes and Cole's (1984) study, subjects often responded to traffic signs without reporting that they had seen them.

Archival studies. Archival studies have also been used as an indication of the effectiveness of conspicuous devices. These studies make use of accident reports, checking to see what conspicuity devices were employed. Alternatively, analysis is made of changes in accident rates after the introduction of compulsory conspicuity measures. This method of analysis is extremely important as it is a good way to validate the results of experimental work. No matter how good experimental work is, it only approximates the real-world situation and so may never be completely valid.

Fulton et al. (1980) gave 950 motorcyclists free safety garments. After a year they sent these subjects questionnaires about their accident involvement. Thirty three percent of subjects had been in an accident or had a near miss. In 45% of accidents or near accidents the motorcyclists had been wearing their safety clothing. In near miss cases, around 50% had been wearing the safety clothing. However, in accident situations, only 13% had been wearing the safety clothing provided. This was thought by the authors to indicate that in these situations, the driver of the other vehicle had been able to avoid those in conspicuous clothing due to earlier detection.

Vaughan (1976) collected survey data on the wearing rates for different helmet colours. They compared this information with crash data and checked for under- or over-involvement in accidents for different helmet colours. It was found that darker coloured helmet colours were over-represented in the figures. For example, 15% of motorcyclists wore black helmets, while 21% of motorcycle accidents involved riders with black helmets. Lighter coloured helmets were under-represented. Around 40% of riders wore white helmets, while these riders only accounted for 35% of accidents.

The limitations of this method are obvious, with the possibility that safety conscious riders are more likely to wear bright clothing. There are two possible ways to overcome this methodological limitation.

Firstly, controlled studies may be made that randomly assign the conspicuity aid to different groups. For example, a study may be conducted that distributes different coloured helmets to members of a group, and later assesses the accident rates of these wearers. Such a method may have ethical problems, in that giving low conspicuity aids to some riders may increase their chances of having an accident.

An alternative method is discussed by Thomson (1980), who analysed motorcycle crashes where the rider had no time to take evasive action. This meant that no matter how safety conscious the motorcyclist was, this would have no impact on the occurrence of an accident. It was found that those riders wearing highly conspicuous clothing were under-represented in the accident statistics.

Janoff and associates (cited in Williams & Hoffman, 1977) conducted a much cited analysis into motorcyclist accidents using archival data. They examined four states in the US that had introduced compulsory use of headlights in the daytime. They did their analysis by comparing each of these four states with similar states, matched for factors like proximity, climate and number of motorcycle registrations. This study found that there were only small differences in the motorcycle accident rates due to the introduction of this law.

This examination is used as the basis for criticism of the conspicuity approach. It is suggested that if the conspicuity treatment that is often considered to be one of the more effective in increasing conspicuity (the use of headlights on motorcycles during daytime) had little influence on the accident rates, then other conspicuity aids will have even less.

Williams and Hoffman (1977) raise major criticisms of this study. They claim that even though the four experimental states (those states that had introduced compulsory headlight use) had been matched to control states, this match was not carried through for the whole study. Instead of comparing the data from each state with the control State to find the difference in accident rates attributable to the change in legislation, the data from the four experimental states were combined. Williams and Hoffman consider this inappropriate, as the legislative changes in each state were vastly different, making a valid comparison dubious. They also criticise the study for the reason that they analysed all accidents, and not specifically those that are thought to be related to conspicuity. As an example, they included data from single vehicle accidents (i.e., where motorcyclists fell of their bikes) in the analysis.

A further criticism is that in three of the four experimental states legislation other than the compulsory use of headlights had been introduced. This included measures such as changes to the licensing regulations, number of passengers, lane usage, brakes, and helmet usage. The impact of these additional changes is unclear, and may have reduced the effectiveness an introduction in compulsory headlight use would have produced.

Williams and Hoffman (1977) re-assessed the data from the study by Janoff by comparing the accident rates for single vehicle (accidents where conspicuity plays no role) and multivehicle accidents (accidents where conspicuity can have an influence). They found that in all cases, the decrease in multivehicle accidents was far greater than for single vehicle accidents. Of particular interest were the results for the one state where the only legislative change was the introduction of compulsory headlights. In this state, multivehicle accidents fell by 16%, while single vehicle accidents increased by 8%.

Shutter technique. Donne and Fulton (1985) developed a novel technique for assessing conspicuity. They had subjects sit in a car facing the oncoming traffic. The experimenter controlled a shutter in front of the subject allowing them a short glimpse of oncoming traffic. The subjects were asked to describe what they saw of the leading vehicle. The glimpse length was determined for each subject so as to make the task of identifying an oncoming vehicle not too easy or too difficult. The target vehicle (a motorcycle) drove past the experimental vehicle on a number of occasions with the rider wearing various conspicuity devices. Ninety percent of glimpses given to the subject were of other vehicles or empty road, so as to not alert the subject as to the purpose of the experiment.

The benefits of such a method are that it is conducted in a natural road environment and that it does not depend on memory, as do recall experiments. The disadvantages are that such a method requires a long period of data collection to provide significant results. Wulf et al. (1989a) also suggest that presentations of the target vehicle were over-represented with 10% of presentations being of the motorcycle, while in the real traffic situation they form only 1% of traffic.

Slide presentations. Presentation of slides have also been used as a method of assessing conspicuity, with a number of variations. Siegel and Federman (1965) conducted a study to determine the minimum time thresholds necessary for the detection of various colours. They found that fluorescent colours required less presentation time to be detected than normal colours.

Fulton et al. (1980) and Stroud et al. (1980) conducted experiments using the presentation of slides to determine the time needed to detect various conspicuity treatments. They photographed motorcyclists wearing a number of conspicuity aids, and used the mean reaction time for a number of subjects as the measure of conspicuity for each aid. It is assumed that the faster an object is seen, the better its conspicuity.

There are two main advantages to this method of analysis. The first is that it allows faster presentations of stimulus than the various field techniques. With faster presentations, more data is able to be collected in the same amount of time, making this a statistically more powerful method. Secondly, the degree of control obtained is far greater in the laboratory situation than is possible in field trials. This means that only the factors that are to be analysed are altered (e.g., target colour). In field type experiments, many extraneous variables may have an influence on the results. It is however recognised that this is an exploratory technique, the results of which need to be validated in 'the real world'.

A problem with such research is that it is difficult to check to see whether the subject has actually seen the target before they make a response. It would be possible in an uncontrolled experiment for the subject to indicate that they had seen the target when in fact they had not. A number of techniques have been devised to curtail this problem.

A number of authors have required subjects to identify some aspect of the target as a way of confirming that it had been seen. For example, Boersema and Zwaga (1985) had subjects indicate the direction an arrow was pointing in their analysis of routing information signs. Other analyses have required subjects to name the type or colour of a treatment condition (e.g., Williams & Hoffman, 1977).

A problem with this technique is that it requires the subjects to learn the different possible targets prior to the experiment. This is both time consuming, and may not be possible in some situations. For example, in the situation where different colours are almost identical, it may not be possible for the subject to differentiate between colours in a short space of time, but there may still be a difference in the reaction time for each. A further problem is that this does not indicate the detection time of a target, but rather measures detection time along with the time it takes to make a decision. It should be noted that this may be of interest in some examinations of conspicuity, particularly in applied situations, but most investigations require only the detection times for each treatment.

A second method used to ensure subjects are identifying the target is by requiring them to indicate the portion of the screen in which the target appeared in (e.g., Cole & Jenkins, 1982, 1984; Boersema & Zwaga, 1988). The screen may be separated into a number of squares, and each of these numbered. After the target is presented the subject must call out the square number in which the target appeared.

Again there are the problems of the extra experimental time required for this method, and that the task of naming the square has to be learned. This has been found to be a difficult task for subjects to learn, as indicated by the large number of mistakes that are made in sector identification, even for easy target presentations (Boersema & Zwaga, 1988). A further problem is that this technique also measures decision making time along with time to detection.

Catch trials have also been used as a way to defend against false reports of targets (e.g., Stroud et al., 1980; Williams & Hoffman, 1977). Typically this method requires the presentation of slides where there are no targets. Subjects are informed of the presence of these slides prior to the experiment, and so are not able to indiscriminately press the response key. Rather they must actively search for the target to make certain it is there before indicating so. The advantage of this technique is that it is quick, with only a small number of catch trails needed for it to be effective.

A method that has recently been developed to ensure that subjects have seen a target before they indicate its presence utilises eye movement detection equipment (e.g., Boersema et al., 1988, 1989; Bradford, 1992). Subjects are shown presentations and are asked to locate targets. Their eye movements are recorded and later analysed to ascertain whether the target had been seen. Such a method is good as it accurately assesses whether the target has been identified, and does not interfere with the detection task (i.e., there is no learning task involved, and subjects do not need to make any decisions as to target orientation or identification). This method allows fast detection of data, and therefore enables more powerful designs.

A second problem that has been identified with the slide presentation method is that the colour reproduction may not be very good (e.g., Thomson, 1982). This was especially the case with earlier studies where the technology for accurate colour reproduction was not available. Even so, this may still remain as a problem and should be monitored in such experiments.

Order of detection. Bradford (1992; Bradford et al., 1992) used the order of target detection rather than detection time in a study of forestry worker conspicuity. Five target colours were shown to subjects in each presentation. They were required to identify the order that they saw these. This method has the advantage that it is a fast way to display a large number of presentations. However, a problem with this type of study is that as targets were often grouped closely together they were frequently perceived as a group, so it was not possible to identify any one target colour as having been detected first.

In conclusion, there are a number of different methodologies that have been used in the investigation of conspicuity. Most have their own advantages over other methods, and all have their own particular draw-backs. In general, field studies are less controlled but more ecologically valid.

The Current Analysis.

It has been noted that there are a large number of cyclist accidents each year, the most serious of which occur when a motorist collides with a cycle. A number of such accidents are the result of low cyclist conspicuity. It is probable that with an increase in the conspicuity of cyclists, there will be a reduction in the number of such accidents. The most practical way to increase the conspicuity of cyclists is by increasing the contrast between the cyclist and their background, particularly with the use of fluorescent colours. It was decided that various colours should be tested against backgrounds that cyclists typically appear against. Three fluorescent colours were identified (e.g., Bradford et al., 1992; R. Parker, personal communication, 15 February, 1994) as increasing conspicuity. These were lime/yellow, pink and orange. Also three non-fluorescent colours were assessed. Red and white were chosen as they are often assumed in the literature and in popular belief to increase conspicuity (e.g., Solomon, 1990; Rumar, 1980). Black was chosen because it has a minimal effect on conspicuity (Shuman, 1991) and may be used as a form of control. Two background illumination levels were used with each of the background colours. This is because it is important to assess conspicuity both in full daylight, and in dull or overcast conditions.

The slide presentation technique was adopted as the method of analysis in the present study because it was considered to be the best exploratory method of analysis available. The eye movement recorder may be the best method to adopt as the test of whether the target object had been seen before a response was made, but the technology required was not available to the experimenter. The use of catch trials was considered the next best method to adopt.

An attempt was made to explore the influence that cognitive aspects have on conspicuity by using a tracking task. This was a relatively difficult task that simulated driving, and was designed to exert a high cognitive demand. This 'driving' task also allowed the presentation of targets to occur in the periphery of the subject's visual field, the place where targets are usually first detected (e.g., Wulf et al., 1989a).

METHOD

The experiment consisted of two parts, the target detection task and a distraction task. The distraction task served two purposes. First it allowed the presentation of the slides to occur in the periphery of the subject's visual field, and second it was used to cognitively mimic the task of driving.

Three different background colours were tested: Green for foliage, grey for concrete and blue for sky. Each of these three colours was tested in two different illumination conditions: bright and dull light, giving a total of six background conditions. Against these backgrounds, six different target colours were tested: fluorescent lime/yellow, fluorescent orange, fluorescent pink, red, white and black. Each of these combinations was tested in four different screen positions. All four of these variables (background colour, background illumination, target colour and screen position) were tested as within-group factors. Reaction time, or the time it took a subject to detect the presence of a target colour, was the dependent variable.

Subjects

Forty acquaintances of the experimenter were used as subjects. Each was tested for visual acuity using Snellen standardised letters of the alphabet (for a discussion of this see Riggs, 1966). Only subjects with 3/6 (corrected or uncorrected) vision, which is equivalent to the licensing criterion in the 1985 Transport (Drivers Licensing) Regulation (Transport Act, 1962), were used in the experiment. Each subject's colour vision was tested using the Farnsworth-Munsell 100-Hue Test (Farnsworth, 1957). Again, only subjects with normal or above normal colour vision were permitted to complete the experiment. Only one subject was excluded from the experiment due to these requirements.

The age of the subjects ranged between 19 and 40 years with the mean being 24.8 years. There were 24 males and 16 females. Ten of the subjects wore glasses or contact lenses.

Apparatus and Materials

Target detection task

The target detection task involved the presentation of 160 slides to each subject. These slides were produced by photographing various backgrounds at intersections around the University of Canterbury campus. A Pentax P-30N camera was used with Kodacolor Gold 100 35mm film.

Three colours were chosen to represent typical intersection backgrounds. Grey was chosen to depict roads and buildings; green was chosen to represent foliage; and blue was picked to represent the sky. The backgrounds (especially for the grey and green conditions) were chosen so as to allow the inclusion of several hues for each colour. Each of these three background colours was photographed under two different illumination conditions: dull and bright light. The bright condition was photographed at mid day, while the dull condition was photographed late in the day. The illumination condition for each photograph was measured using a Toshiba Photocell Illuminometer (Model SP1-5). The results are summarised in Table 1. The same scene was photographed for each of the two illumination conditions. This meant that the only factor to vary between each pair of photos was the level of illumination, and not such factors as scene complexity. Previous research (e.g., Jenkins &

Cole, 1982) has found that factors such as complexity have an influence on conspicuity.

Table 1

Illumination Readings (lux) for Each of the 6 Backgrounds at the Time of Photographing.

	Light	Dark
Green	1960	290
Blue	2156	200
Grey	6370	480

Each of the six backgrounds can be seen in Figures 1 to 6

Figure 1. Light blue background condition

Figure 2. Dark blue background condition

Figure 3. Light green background condition

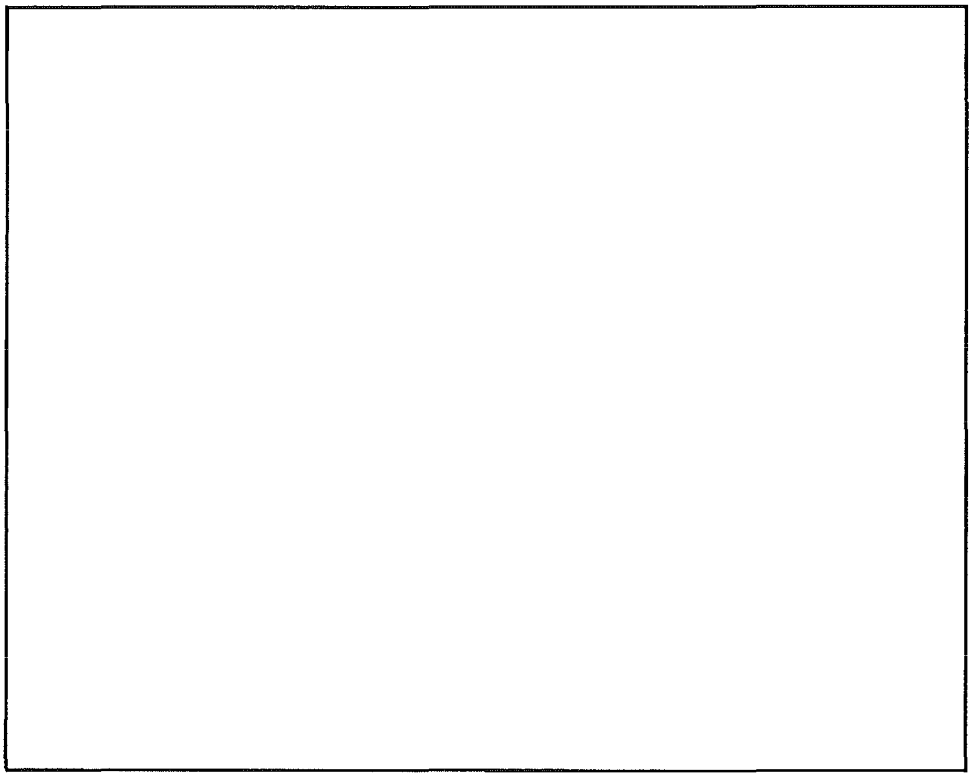

Figure 4. Dark green background condition

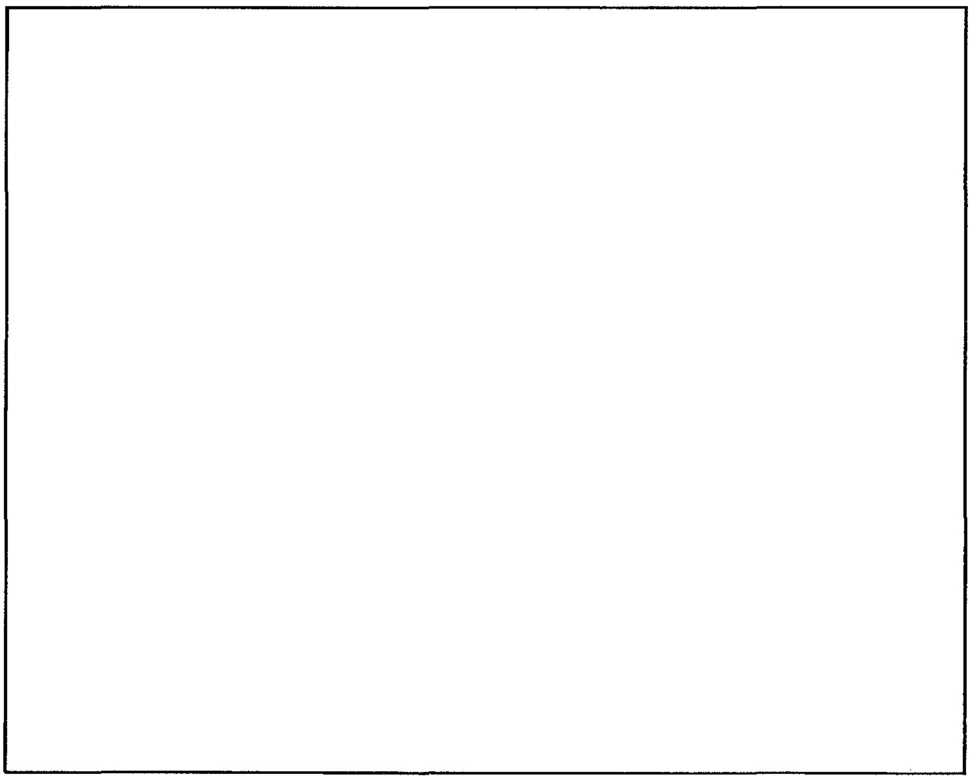

Figure 5. Light grey background condition

Figure 6. Dark grey background condition

Standard sized photographs were enlarged to 12 inch by 8 inch prints. In the Psychology Department photographic laboratory 35mm transparencies were taken of these enlargements with the target colours embedded on them. A Pentax K1000 camera was used with Kodak 100 Professional Color Reversal (slide) film. Two Metz Muablitz Twin flash units where also used to keep the lighting level constant while photographing (i.e., to reduce the effects of such factors as hot spots and shadows).

Six different colours were tested against the six backgrounds. Three were fluorescent: lime-yellow, orange and pink. The other three were of matte finish: red, white and black. Samples of these colours can be seen in Figure 7.

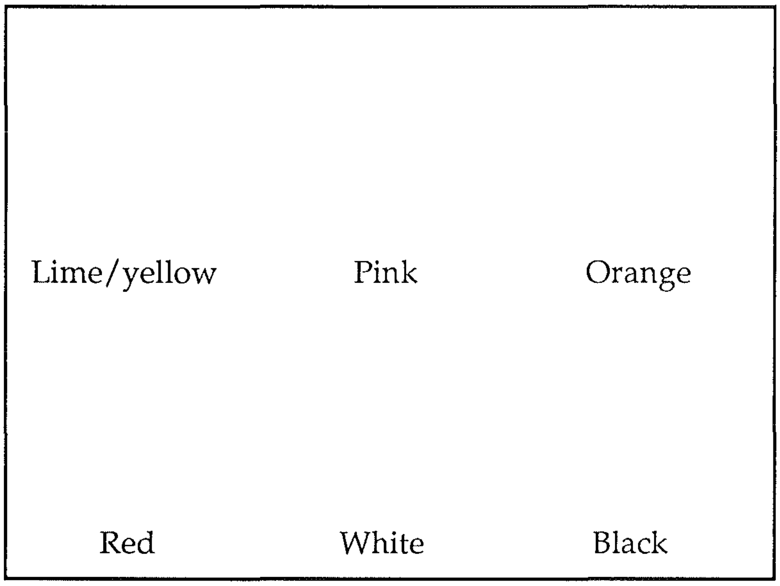

Figure 7. Examples of the 6 different target colours.

A 3mm by 3mm sample was taken of each test colour and embedded against each of the six backgrounds. Each background was divided into four columns to test for any effect that the angle or distance to the target may have on detection of the target colours. Targets in the far-left position were 35 deg from the subject's line of sight. Those in the mid-left were 45 deg. In the mid-right position, the targets were presented 55 deg from the line of sight, while those in the far-right were 65 deg from the line of sight. Each test colour was placed in a random vertical position in each of these four columns. The combinations of 6 (backgrounds) x 6 (target colours) x 4 (target positions) produced a total of 144 target slides.

In addition to the 144 target trials, there were 16 catch trials. The slides for these were produced using the same backgrounds as those used with the target slides, but no target colours were present. These catch trials were included to ensure that subjects were actually detecting the targets and not merely reporting that they had been seen. Subjects were informed before the experiment began that not all slide presentations would contain target colours, and so they would not be able to automatically press the response key on the presentation of a slide. Rather, they had to search the slide presentation for the presence of a target.

These 16 catch trails gave a total of 160 slide presentations (i.e., 10% of all presentations). The 160 slides were then randomised with three constraints: No one background condition (i.e., background colour or illumination), or column position was repeated more than twice in a row. Eight different random orders of slide presentations were produced using these constraints. The first two randomisations (order 1 and 5) were produced from a random number table. As there were two trays of slides (each holding 80 slides), every alternate subject was shown a different tray first, producing orders 2 and 6. Orders 3 and 7 were produced by reversing the presentation order from orders 1 and 5. Finally, orders 4 and 8 were produced by again alternating the tray that a subject was shown first. This ordering was employed to control for any effects due to sequence, order or learning.

The slides were projected using two Kodak Carousel S-AV 1010 slide projectors. Each of these projectors held 80 slides. The central computer automatically switched between projectors after all the slides had been shown in each tray. The computer was connected to an IDAC/1000 (International Data Acquisition & Control, Inc.) control unit. This was connected to a Lafayette Instrument Company 43017 shutter control (see Figure 8). Through these devices, the computer was able to control the presentation of the slides, and was also able to advance the slide projector.

Figure 8. Slide projection equipment

Distraction task

The distraction task was presented to the subject on the screen of a Macintosh LC 11 computer. The task was a relatively simple spatial task, although it was sufficiently difficult to require the subject's full attention. The distraction task was designed to cognitively simulate the task of keeping a car in the centre of the road. Using the computer mouse, the subjects were required to keep a cursor inside a box that moved randomly left and right on the computer screen. The speed of the box was altered randomly (i.e., it went faster and slower), as was the point on the screen at which it changed direction. An example of the task is shown in Figure 9.

Figure 9. Example of distraction task

Each time the subject was unable to keep the cursor within the target box they were alerted by a tone emitted from the computer. The proportion of time (as a percentage) that the cursor strayed was also recorded by the computer. This was used as a performance measure of the effectiveness of each presentation of the distraction task. The higher this percentage of time, the less effective the distraction task.

The distraction task was presented for a randomly determined time of between 3 and 7 seconds. This time was made variable so that the subject was unable to anticipate when the distraction task would end, and so anticipate when each slide would be presented. This ensured that each presentation of the target detection task was in the periphery of the subject's visual field.

Procedure

Subjects were tested individually in an experimental laboratory in the Psychology Department. Prior to the experiment, subjects were tested for visual acuity and colour vision. They were then familiarised with the experimental room. Figure 10 shows the layout of the room.

Figure 10. Layout of the experimental room.

Subjects were seated 60 cm from the computer screen, and 105 cm from the centre of the slide projection screen. Using the formula for visual angle (Graham, 1966) it was found that the computer screen subtended 23.9 deg horizontally, and 19.1 deg vertically of the visual field, while the distraction task target box subtended 3.3 deg. The slide screen subtended 21.8 deg horizontally and 14.7 deg vertically of the visual field, while each target subtended 0.22 deg.

Subjects were next given instructions on what they were required to do (see Appendix A). Next they were allowed to practice the distraction task until they were able to handle it competently. This required that the subject be able to complete two full cycles (i.e., the box moving from the left of the screen to the right and back again) without allowing the target box to stray from around the cursor. Subjects were also shown what they were to look for using several example slides. Once subjects were comfortable with what they were required to do, the experiment began.

Before each slide was presented, the subject was required to perform the distraction task. This occurred for a random length of time between 3 and 7 seconds. The subjects were required to track the randomly moving box using the cursor. The computer monitored the percentage of time that the subject failed to keep the cursor inside the box.

Following the randomly determined time, the computer screen displaying the distraction task blanked out, and the slide projector was engaged. At the same time the reaction time clock in the computer was started. The subject was required to click the mouse as soon as a target was detected. If no target was detected the slide was displayed for six seconds. This length of time was estimated to be well in excess of the maximum time needed by the driver of a car for a glance at an intersection (e.g., Hills, 1980, suggests that in the driving situation, we typically have one to two seconds in which to make critical decisions).

The computer recorded the reaction time, or the time from the onset of the presentation to the depression of the response key on the mouse. Also, the percentage of time that the subject failed to keep the cursor inside the box during the distraction task was recorded. The slide projector was then advanced automatically by the computer, and the distraction task restarted. This cycle was then repeated 160 times, until all the slides had been shown. Reaction times and performance criteria were recorded in a file by the computer.

Design

This study was a four-way within-subject design. The independent variables used in the study were target colour (with six levels), background colour (three levels), background illumination (two levels) and the screen position that the target appeared in (four levels). The dependant variables were the reaction time, or the time it took the subject to press the response key on the mouse after the presentation of the stimuli, and performance in the distraction task.

RESULTS

When all subjects had completed the experiment, data files were loaded into a spreadsheet for formatting into the correct style for the data analysis package. Results were analysed using the CLR Anova package for the Macintosh (Clear Lake Research, 1986), and SPSS for Windows (1993) on IBM PC computers. The raw data from each subject was manipulated into the correct format using Excel on the Macintosh (Microsoft Excel, 1992). Different slide presentation orders were converted into the one order for easier analysis. A four-way within-subject analysis of variance was performed on both the distraction task and reaction time data. Results from each of these two analyses will be discussed separately.

Distraction Task

The primary purpose of the distraction task was to make sure that slide presentations were made in the periphery of the subject's visual field. Performance on this task was recorded to determine whether the subjects were looking at the slide presentation screen, rather than the computer screen when slides were presented. A low error rate in the distraction task would suggest that the subjects were attending to the computer screen.

In trials where the distraction task was not monitored by a subject, it was found that the percent of time in error (time that the cursor strayed from the target box divided by the total time that the distraction task appeared on the screen) was 72%. It was reasoned that if a subject was not observing the distraction task, they would have to be scoring at a similarly high error rate.

Errors for the distraction task ranged from 0% to 67%, with the mean error rate being 6.18%. Figure 11 shows that in 95% of presentation trials the error rate was less than 20%. Considering the difficulty of the task, this was considered to be an adequately low error rate. The error rates for individual subjects ranged from 1.9% to 13%, with the mean being 6%.

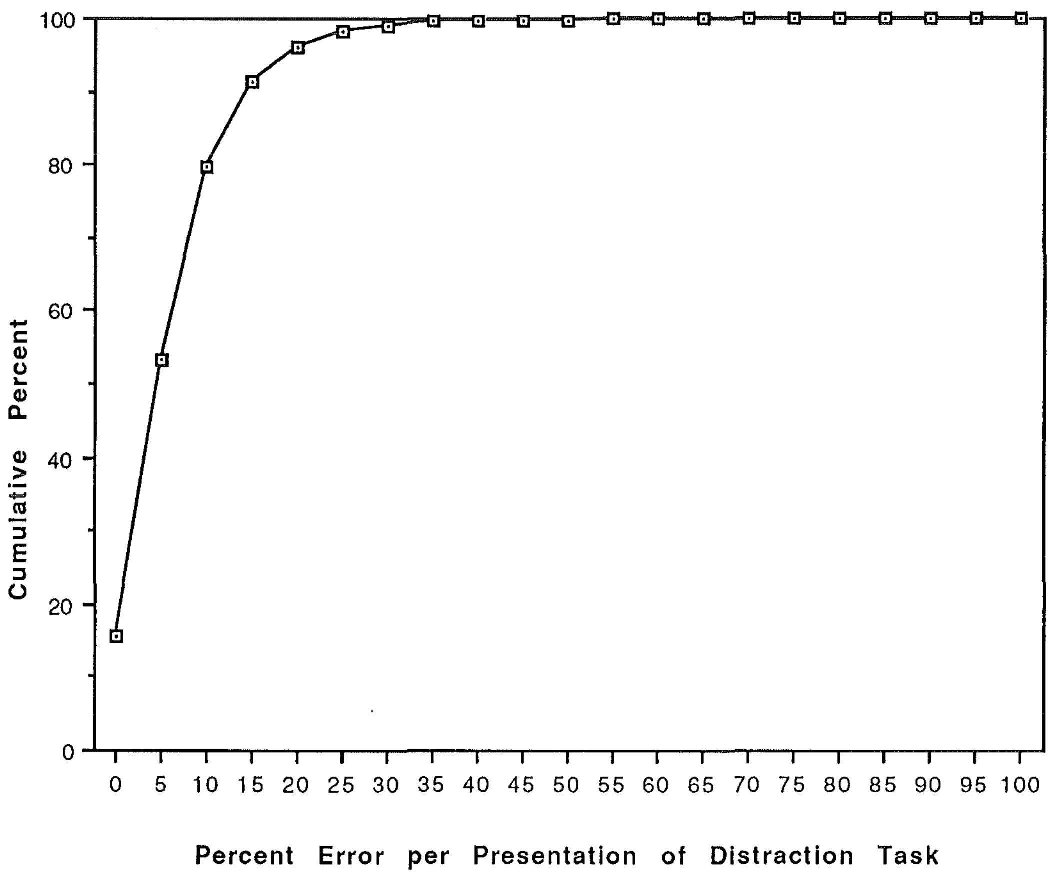

Figure 11. Cumulative percent error rate in distraction task

The experimenter observed that those with high error rates in the distraction task were having difficulty with the distraction task, and were not in fact glancing at the slide presentation screen.

As a check, an ANOVA was conducted to determine whether there was any interaction between the within-subject variables and a high distraction task score. If an interaction was detected in this analysis it could be concluded that in the significant condition, subjects were more likely to be looking at the slide presentation screen before a slide was presented, giving potentially faster reaction times for that condition. The ANOVA showed that there were no significant interactions between the different conditions and performance in the distraction task.

Target Detection Task

In the target detection task, the time from when the slide was displayed until the subject hit the response key on the mouse was recorded by the computer for each slide presentation. This reaction time was recorded with an accuracy of 1/60 th of a second (0.0167 secs). Results for the catch trials will be presented first, followed by an examination of the main effects, then the interaction effects.

Catch trials

Ten percent of all presentations were catch trials. It was found that out of the 640 catch trials (i.e., when there were no targets), targets were reported on 18 occasions, or 2.8% of all catch trials. Of the 40 subjects, 22 (55%) correctly did not report a target on any of the catch trials, 13 (33%) falsely reported a target on one catch trail, and five (12%) erred on two catch trials. As can be seen from Figure 12, slides with a dark grey background presented the greatest problem to subjects, with 15 false reports of targets (83% of all catch trial errors).

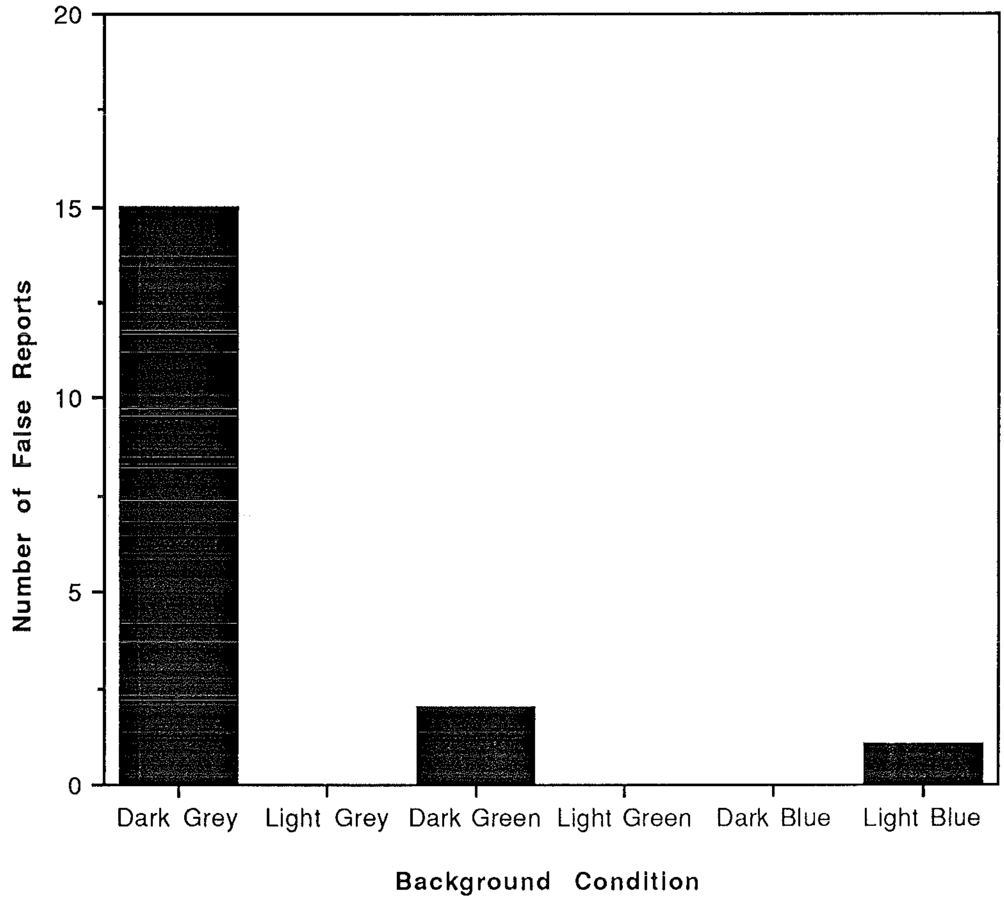

Figure 12. Number of targets falsely reported by background condition

A table was constructed to analyse the result for the dark grey condition for any response bias (see Table 2). Of those presentations where there were no target in the dark grey background condition, 87.5% of responses (105 out of 120 presentations) were correct with the report of no target seen, whereas targets were falsely reported on 12.5% of presentations (15 out of 120 presentations). In the case where there were targets presented, 84.2% of responses were correct indications that the target had been seen (809 out of 960 presentations), while 15.7% of responses were incorrect, with the target not being seen (151 out of 960 presentations).

Table 2

Responses (as a proportion) for dark grey backgrounds

		Report: No Target	Report: Target
Event	No Target	0.875	0.125
	Target	0.157	0.842

As there was around the same proportion of response errors for when there was a target reported as for when there was no target reported, there was no reporting bias in subject's responses. This means that the number of errors in this condition were the result of some other factor (see discussion section).

Main effects for target detection task

Mean reaction times for each condition of the main effects, as well as the percent of targets not seen in each condition can be observed from Tables 3 to 6. The longer the reaction time and the higher the percent of targets not seen, the less conspicuous the target in that condition. The mean reaction without those trials where a target was presented but not seen within the six seconds allowed were also computed for each condition. Where the percent of targets not seen was the greater, there will be a larger reduction in the reaction time with this data removed. As can be seen when comparing these adjusted means with the unadjusted means, there was little difference in the structure of the data.

Table 3

Mean Reaction Time and Percent of Targets Not Seen for Target Colour

Target colour	Black	Orange	Pink	L/Yellow	Red	White
Mean RT (sec)	4.92	1.12	1.20	1.03	1.45	2.01
Adjusted RT (sec)	2.01	1.11	1.19	1.02	1.37	1.30
% Not Seen	72.80	0.03	0.02	0.01	1.70	15.10

Table 4

Mean Reaction Time and Percent of Targets Not Seen for Background Colour

Background Colour	Blue	Green	Grey
Mean RT (sec)	1.26	2.09	2.52
Adjusted RT (sec)	1.04	1.29	1.44
% Not Seen	4.40	17.00	23.70

Table 5

Mean Reaction Time and Percent of Targets Not Seen for Background Lighting

Background Lighting	Dark	Light
Mean RT (sec)	1.69	2.22
Adjusted RT (sec)	1.07	1.40
% Not Seen	12.50	17.50

Table 6

Mean Reaction Time and Percent of Targets Not Seen for Screen Position

Screen Position	Far-left	Mid-left	Mid-right	Far-right
Mean RT (sec)	1.84	1.77	1.83	2.38
Adjusted RT (sec)	1.18	1.05	1.18	1.56
% Not Seen	13.70	14.60	13.50	18.40

As can be seen from Figure 13, the percent of targets not seen correlate closely with the mean reaction times.

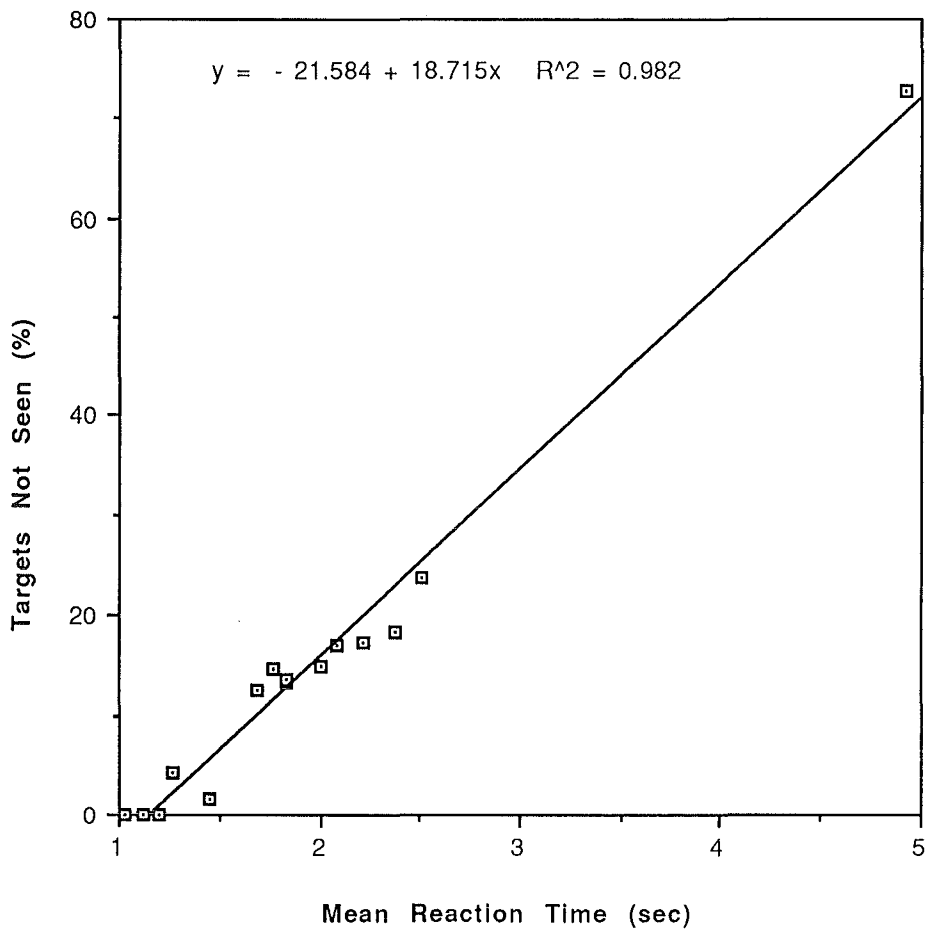

Figure 13. Percent not seen plotted against mean reaction time for main effects

Conditions where subjects were slow to react to the presentation of a target generally had a higher percentage of targets not seen, indicating that both variables access difficulty. For this reason, only reaction times for each condition will be discussed. This high correlation also indicates that there is no speed accuracy trade-off in this analysis. With a faster detection of targets, there was not a corresponding increase in the number of errors.

The adjusted reaction times (i.e., excluding presentations where the target was not seen) were correlated against the percent of targets not seen. It was found that there is a much smaller correlation between the percent of targets not seen and the adjusted means than was found when percent of targets not seen was correlated against the unadjusted reaction times (0.68 compared with 0.98). The unadjusted means were thought to be of greater use as these data points were a more accurate indication of how hard particular targets were to see. It is possible that if the length of time the subject had to search for a target was increased, they would have found more. This would have resulted in longer search times for these conditions. Leaving out those means where targets were not seen would have produced artificially low reaction times for those targets that were hard to see. Also, the statistical packages used in this analysis were unable to analyse the data without including presentations where the target was not seen. For these reasons the unadjusted reaction times were used in the statistical analysis of the results. After conducting an ANOVA, it was found that all four of the main effects were significant (see Appendix B).

Target colour. There was a significant variation among the target colours ($F(5,195) = 3956.1$, $p < .0001$). The reaction times for each of the target colours can be seen graphically in Figure 14.

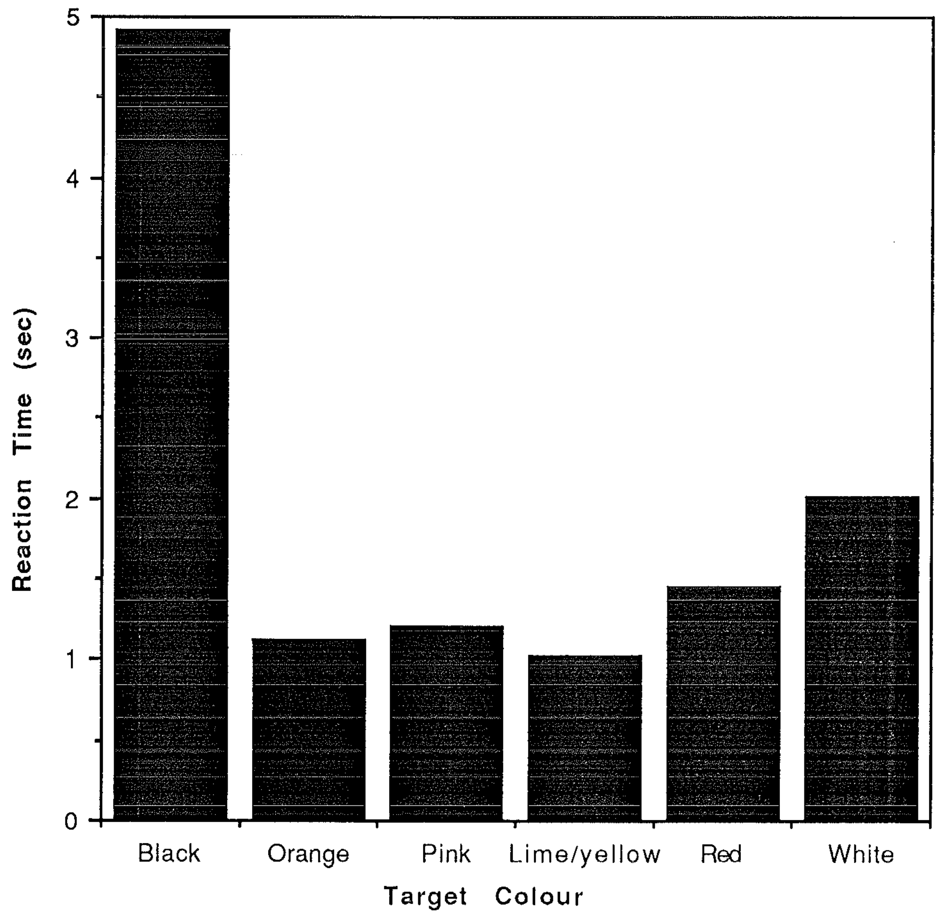

Figure 14. Mean reaction time for each of the target colours

Post-hoc statistical tests were conducted on the data to determine which of these mean reaction times were significantly different from each other (see Appendix C). The Tukey honestly significant difference (hsd) test was used as it is fairly conservative, and therefore less likely to yield a statistically significant result (see e.g., Keppel, 1982). This is important when there are a large number of analyses, as the chance of finding a comparison significant when it is not (a Type 1 error) increases.

The results from this analysis showed that although fluorescent lime/yellow was seen faster than orange over all, it was not seen significantly faster. It was however seen significantly faster than pink ($p < .01$) and all of the non-fluorescent colours ($p < .01$). Fluorescent orange was not seen significantly faster than either of the other fluorescent colours, but was seen significantly faster than all the non-fluorescent colours ($p < .01$). As mentioned, fluorescent pink was seen significantly slower than lime/yellow, but there was no significant difference with the orange colour. Once again, pink was seen faster than all the non-fluorescent colours ($p < .01$). Red was seen significantly faster than white ($p < .01$), and significantly faster than black ($p < .01$), but was significantly slower than all the fluorescent colours. White was seen significantly slower than all other colours excluding black ($p < .01$). Finally, black was seen significantly slower than all other colours ($p < .01$).

<u>Background colour</u>. There was a significant difference in reaction times to the presentation of different background colours ($F(2,78) = 1542$, $p < .0001$). From Figure 15 it can be seen that targets presented against a blue background were seen faster than those against both green and grey backgrounds, and targets with green backgrounds were seen faster than those targets presented against grey backgrounds.

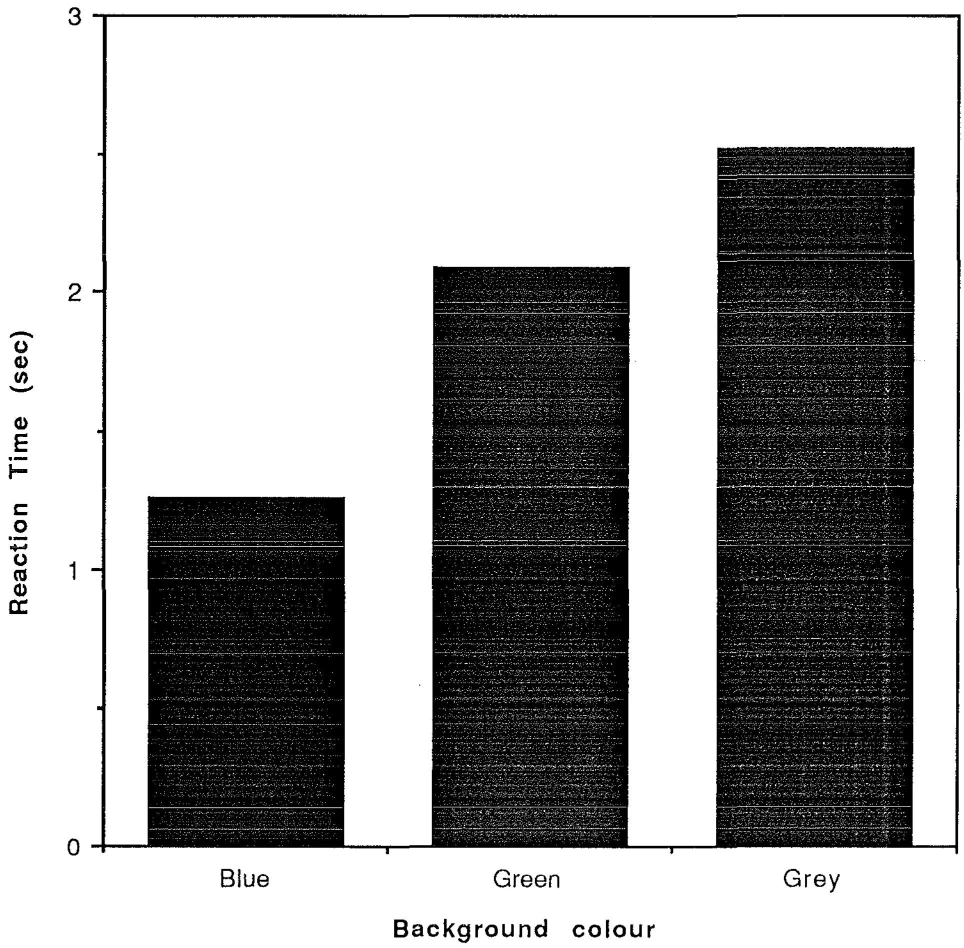

Figure 15. Mean reaction time for each of the background colours.

After post-hoc analysis with the Tukey test (see Appendix C), it was established that all of these differences were significant ($p < .01$).

Background illumination. As can be seen from Figure 16, targets presented against dark coloured backgrounds were seen significantly faster than those presented against light backgrounds ($F(1,39) = 780.3$, $p < .0001$).

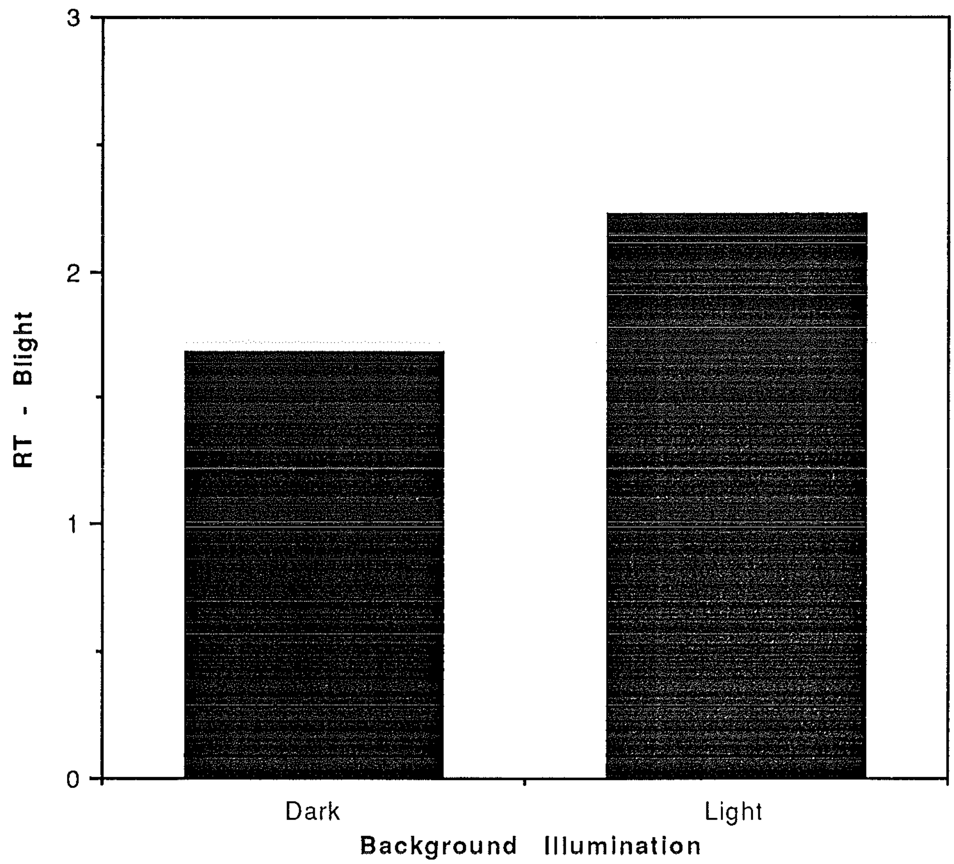

Figure 16. Mean reaction time for background illuminations

Screen position. The results for the final main effect, screen position, can be seen in Figure 17. Again it was established that these means differed significantly ($F(3,117) = 268.9$, $p < .0001$). After conducting Tukey tests (see Appendix C) it was determined that those targets presented in the far-right of the screen (furthest from the subjects) were detected significantly more slowly than those in the other positions ($p < .01$).

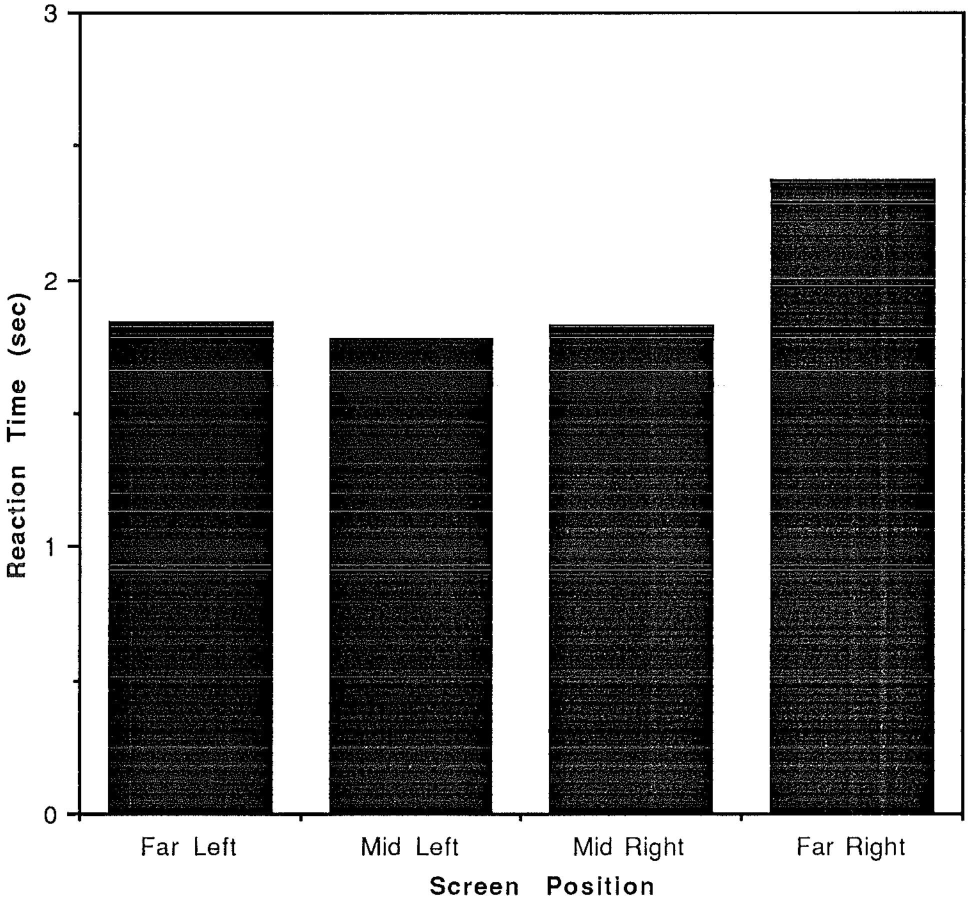

Figure 17. Mean reaction time for each screen position

Also, there was a significant difference in reaction times between targets presented in the far-left, and those presented in the mid-left of the screen ($p < .05$). There was no significant difference between targets presented in the mid-left and those presented in the mid-right of the screen. There was also no significant difference between those targets presented in the far-left of the screen, and those presented in the mid-right.

<u>Interaction effects for target detection task</u>

Along with the main effects there were also a number of significant interactions. Examining the results of the interactions is important, as it is unlikely to be the case that cyclists will be seen against each of the background conditions in equal proportions. For example, it may be more likely that cyclists will be observed against green background colours. Therefore, the results for some conditions will be more important than for others. Also, these interactions help us generalise the results to other geographical regions. For instance, in larger cities we would expect less green colours and more grey. Finally, the interactions let us apply the results to other conditions beyond that of cyclists. We may use this information to examine factors such as which colours school patrols or hunters should wear to be most conspicuous.

First those interactions involving target colour will be examined, as these are the most important factors when deciding which colours are most conspicuous. The other interaction effects will also be examined as these inform us under which conditions objects are least (or most) conspicuous.

Target colour by background colour. There was a significant interaction between target colour and the background colour that these targets were presented against ($F(10,390) = 256.9$, $p < .0001$) as can be seen from Figure 18. Again, a post-hoc Tukey test was conducted (see Appendix C). Against the blue background, there were only small differences between the various colours. There were no significant differences between the three fluorescent colours, and white was also detected just as quickly. Red was seen significantly slower than fluorescent lime/yellow ($p<.01$), but not any of the other colours. Black was detected slower than all other colours against the blue background ($p< .01$).

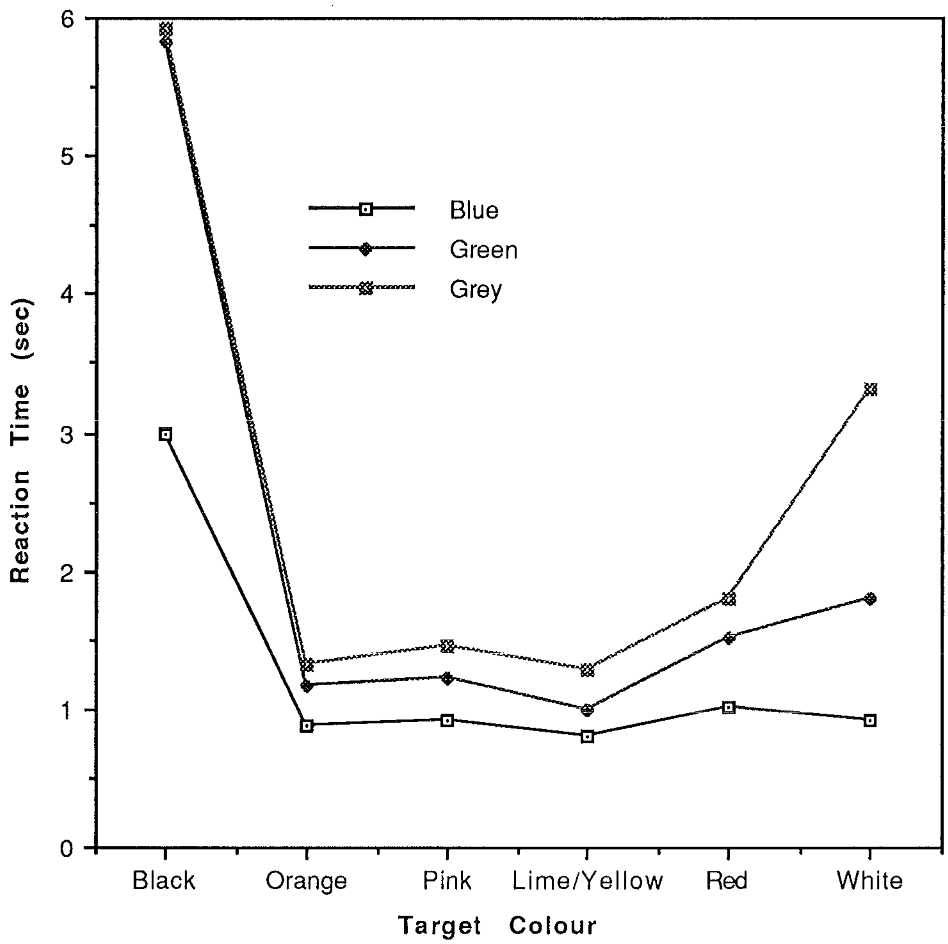

Figure 18. Mean reaction times for the target colour/ background colour interaction.

When presented against the green background, fluorescent lime/yellow was seen significantly faster than all other colours ($p < .01$) except fluorescent orange. There was no significant difference between fluorescent orange and fluorescent pink. Again, the fluorescent colours were all seen significantly faster than all of the non-fluorescent colours ($p < .01$). Red was seen significantly faster than white and black ($p < .01$), and white was seen significantly faster than black ($p < .01$).

Against the grey background there was no significant difference between the fluorescent colours. Again the fluorescent colours were all seen significantly faster than the non-fluorescent colours ($p < .01$). Red was detected the quickest of the non-fluorescent colours, being seen significantly faster than both white and black ($p < .01$). Finally, white was seen significantly faster than black against the grey background ($p < .01$).

The results were also analysed by each target colour. The Tukey analysis for fluorescent orange showed that there were significant differences in response times for targets presented against each of the background colours ($p < .01$), with targets presented against blue backgrounds being seen faster than against green backgrounds, and those presented against green backgrounds being seen faster than those presented against grey backgrounds (as was the case for all of the target colours). The same result was also true for the fluorescent pink targets against each of the background colours.

For fluorescent lime/yellow, there was no significant difference between targets that were presented against the blue background, and those presented against the green, but there was significance for each of these colours when compared to the grey background ($p < .01$). There were significant differences in reaction times to white presentations against the various backgrounds ($p < .01$), as was also the case for the red target colour ($p < .01$). Finally, there was a significant difference for black targets presented against blue backgrounds, and those presented against green backgrounds ($p < .01$), but there was no difference between those targets presented against green backgrounds and those presented against grey.

Target colour by background illumination. There was a significant interaction effect between the different target colours and the background illumination ($F(5,195) = 269.5$, $p < .0001$). This can be seen graphically from Figure 19.

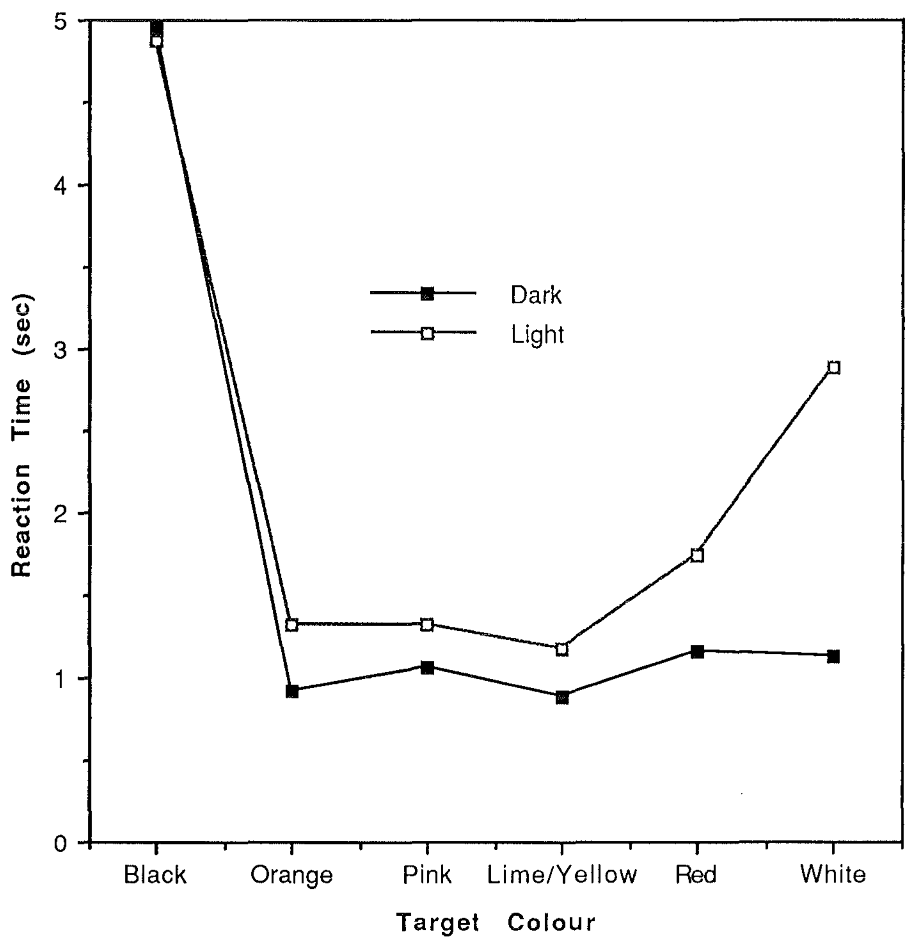

Figure 19. Mean reaction times for the target colour/background lighting interaction.

A Tukey test was conducted on these results (see Appendix C). In the dark condition fluorescent lime/yellow was seen significantly faster than all other colours excluding fluorescent orange ($p< .01$). Fluorescent orange was seen significantly faster than fluorescent pink and all of the non-fluorescent colours ($p< .01$). Of the non-fluorescent colours red was again seen the fastest, with reaction times being significantly lower than white and black ($p< .01$). White was seen significantly faster than black ($p< .01$).

In the light condition fluorescent lime/yellow was seen significantly faster than all other colours ($p< .01$). There was no significant difference between fluorescent orange and fluorescent pink. Of the non-fluorescent colours, red was again seen the quickest, being significantly faster than white and black ($p< .01$). Finally, white was seen significantly faster than black ($p< .01$).

Again, the results for each of the target colours were also examined against each of the background illumination conditions. Each of the fluorescent colours showed significant effects ($p< .01$), with those targets presented against dark backgrounds being seen significantly faster than those presented against light backgrounds.

There was also a significant difference for both the white and the red target colours ($p< .01$) with both colours being seen faster when presented against the dark background. It is interesting to note the large difference for white targets. Lastly, there was no significant difference for the black target colour, with those targets presented against the light background being seen equally as fast as those presented against the dark background.

<u>Target colour by screen position</u>. The two-way interaction for target colour by screen position was also significant ($F(15,585) = 38.4$, $p < .0001$), the results of which can be seen from Figure 20.

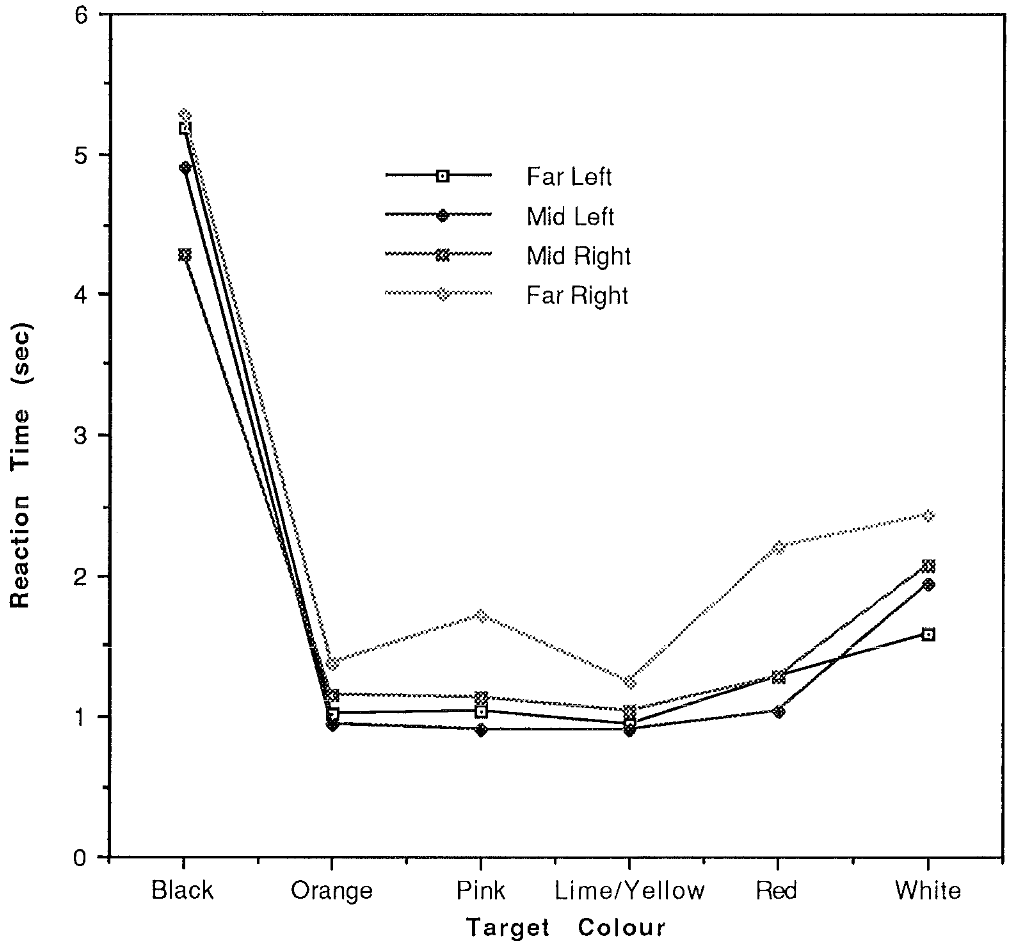

Figure 20. Mean reaction times for the target colour/ screen position interaction.

The statistical package CLR ANOVA was unable to handle a post-hoc Tukey test for this interaction due to the large number of means involved. Instead, a number of Scheffe tests were conducted on the interactions. The Tukey test is considered more appropriate in such exploratory analysis as the Scheffe test is too conservative in such situations (see Keppel, 1982). For this reason it is possible that the analysis conducted for this interaction produced non-significant results (i.e., the two means analysed produced non-significant results) when in fact the two means should have been significantly different. It is therefore concluded that the results for the target colour/ target position interaction should be treated with caution.

There were a number of significant differences in the reaction times for the different screen positions for the fluorescent colours. Generally these results closely followed those of the main effect for screen position as seen earlier. There were two significant differences for the fluorescent orange colour, with those slides presented in the far-left and mid-left of the slide projection screen being seen faster than those presented in the far-right ($p < .05$). For fluorescent pink, targets presented in the far-right of the projection screen were seen significantly slower than all other positions ($p < .0001$), but there was no significant difference between the other three positions. There was only one significant result for fluorescent lime/yellow, with those targets presented in the mid-left of the screen being seen faster than those presented in the far-right ($p < .05$). The interaction between red targets and the screen position followed that of the main effect for screen position also. In this case, targets presented in the far-right were seen significantly slower than those in other positions ($p < .0001$). There was no significance between the other positions for this colour.

The effects for the white targets did not follow the main effect for the screen position condition but rather followed the expected results, with targets further in the periphery producing slower reaction times. Targets presented in the far-left of the screen were more easily seen than those in other positions ($p < .01$), while those presented in the far-right were significantly slower to detect ($p < .05$).

Black targets also did not follow the trend seen in the main effect for screen position. Those targets in the mid-right of the projection screen were seen significantly faster than those targets in other positions

($p < .0001$). Also, for this condition there was no significant difference between those targets presented in the far-left of the screen and those presented in the far-right, although there was a significant difference between those targets presented in the mid-left and those presented in the far-right, with the latter being detected slower.

The results for each of the four screen positions were also analysed with regards to each target colour. There was no significant difference between the different fluorescent colours in the far-left of projection screen. Also, fluorescent lime/yellow was the only fluorescent colour which was significantly different to red in this position ($p < .05$). There was no significant difference between red and white in this part of the slide projection screen, but white was seen significantly slower than all of the fluorescent colours ($p < .0001$). Black targets presented in the left of the screen were detected significantly slower than all other colours ($p < .0001$).

An interesting result from those targets presented in the central screen positions (i.e., mid-left and mid-right) is that there were no significant differences between the red targets or the fluorescent targets. There were however significant differences between these group of targets and the white and black targets ($p < .0001$). Again, black targets were detected significantly slower than all other targets ($p < .0001$).

Finally, there were a number of significant results for targets presented in the far-right of the screen. There was no significant difference between the fluorescent orange and the fluorescent lime/yellow, but there was between these colours and fluorescent pink ($p < .05$ and $p < .0001$ respectively). There were also significant differences between the fluorescent and non-fluorescent colours. As with the far-left condition, there was no significant difference between the red and the white targets. The black targets were seen significantly slower than all of the other coloured targets ($p < .0001$).

Background colour by background illumination. There was a significant interaction effect for background colour by the background illumination level ($F(2,78) = 401.36$, $p < .0001$). These effects can be seen from Figure 21. A post-hoc Tukey test was conducted on these results (see Appendix C). There was no significant difference between the two illumination conditions for the blue background condition. However, those targets presented against the dark green background were seen significantly faster than those presented against a light green background ($p < .01$). Similarly, targets presented against a dark grey background were seen significantly faster than those presented against a light green background ($p < .01$).

Targets presented against a dark blue background were seen significantly faster than those presented against a dark green background ($p < .01$), and these were seen faster than those presented against a dark grey background ($p < .01$). The same trend was seen with the light backgrounds, with targets presented against a light blue background being seen faster than those presented against a light green background ($p < .01$), while those presented against a light grey background were seen significantly slower than both of these ($p < .01$).

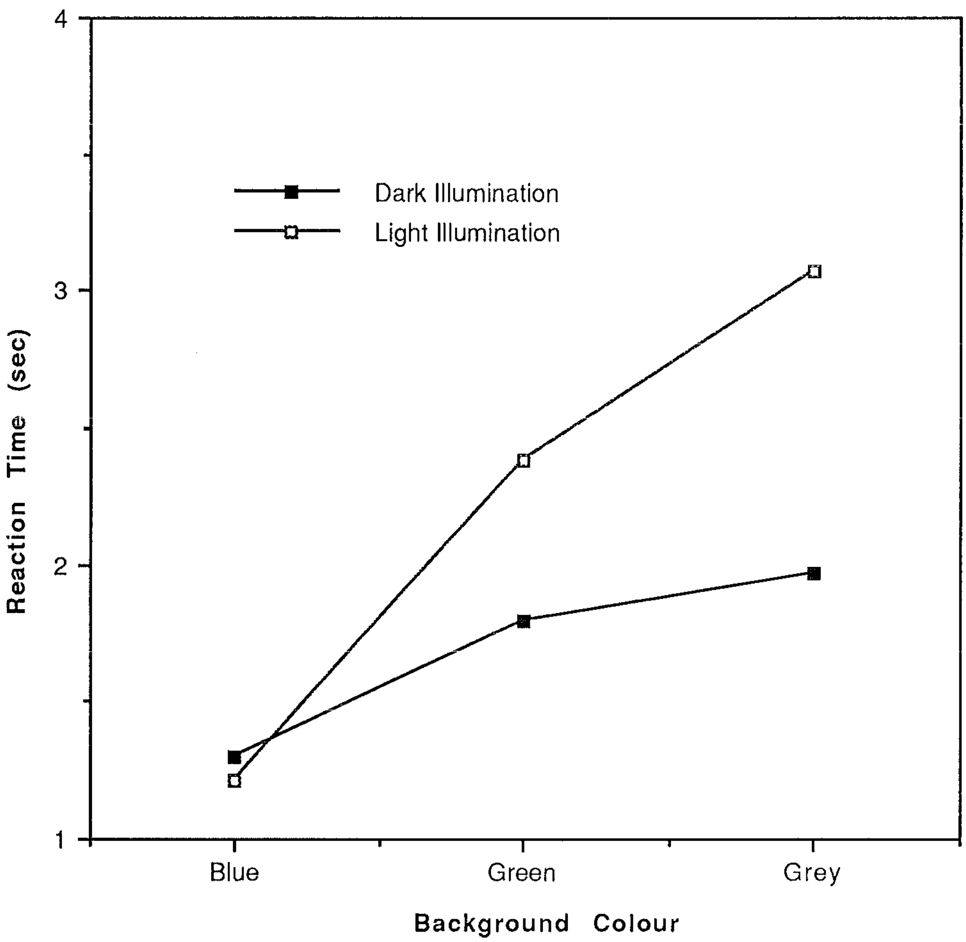

Figure 21. Mean reaction times for the background colour/background illumination interaction.

The two way interactions regarding screen position that do not include target colour were not analysed as they serve little purpose in this study. Along with the two way interactions, there were also some interesting three way interactions.

Target colour by background colour by background illumination. The interaction for target colour by background colour by background illumination proved to be significant ($F(10,390) = 163.7$, $p < .01$), and these results can be seen in Figure 22.

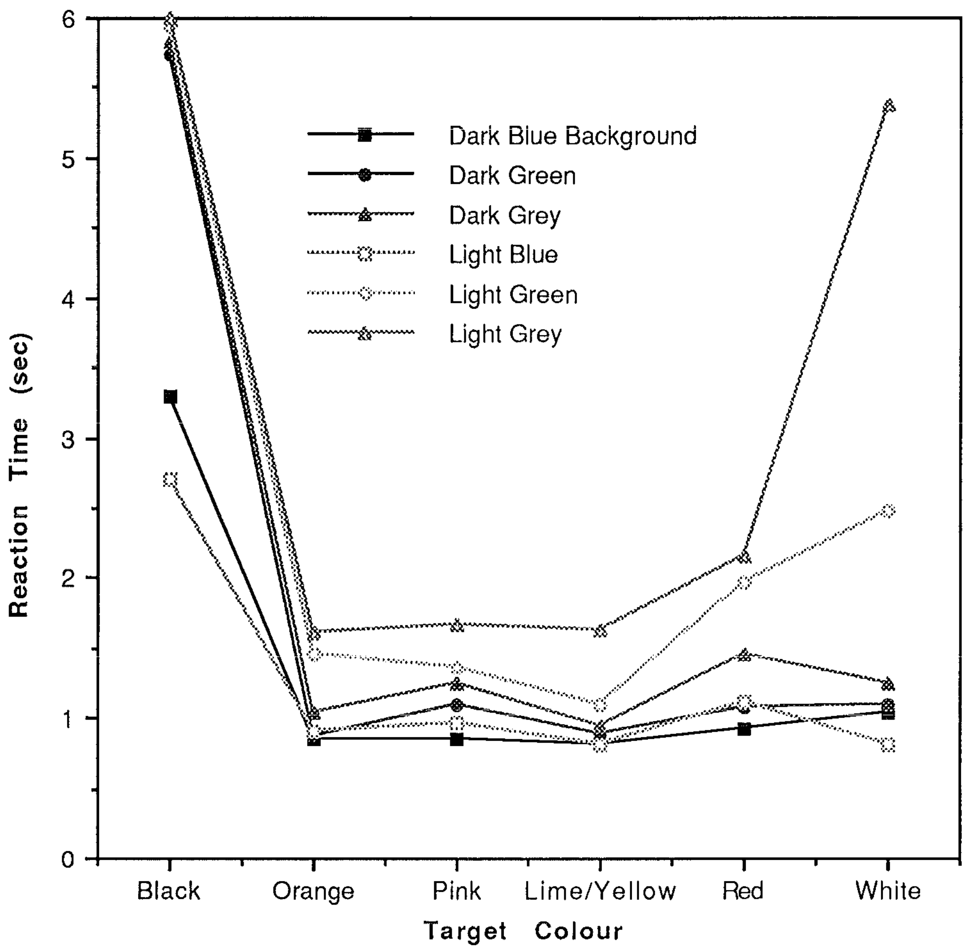

Figure 22. Mean reaction times for the target colour/background colour/background illumination interaction.

Again there were too many comparisons to conduct Tukey post-hoc tests on the data. Also there were too many means to do the Scheffe or any other post-hoc test, so for this analysis (as for the other three-way interactions) only a descriptive examination will be made.

It is quite interesting to examine the results for white target presentations. All but the light grey and light green were seen comparatively quickly, and those white targets presented against a light blue background were seen quicker than all but the fluorescent lime/yellow targets. White targets presented against a light grey background were seen extremely slowly, and were almost comparable to black target presentations. Similarly, red targets were also seen relatively slowly against the light grey and light green backgrounds.

As would be expected from the main effects analysis, light grey targets were the slowest to detect. There appears to be little difference between the fluorescent colours in this condition, but there were large variations with the non-fluorescent colours.

Targets presented against the light green background were generally slow to detect, with the exception of lime/yellow targets. Also in this situation, the pink targets were detected quicker than the orange.

Target colour by background illumination by screen position. The second three-way analysis of interest was the interaction between target colour, background illumination and screen position. This was found to be significant ($F(15,585) = 43.9$, $p < .0001$). Interactions for this analysis can be seen graphically from Figure 23. Here we can see interesting results in relation to peripheral vision and the different targets. Targets presented against the dark background in the right of the screen were seen surprisingly well for both the fluorescent colours and the white targets. This was especially the case for the fluorescent lime/yellow and orange target presentations, which appear to be seen as well as those in the left of the presentation screen.

Light backgrounds presented in the right of the screen seemed to produce the greatest problems. This was the case for both fluorescent and non-fluorescent targets. Red targets were seen well against the dark backgrounds in the left of the screen, but there were problems in

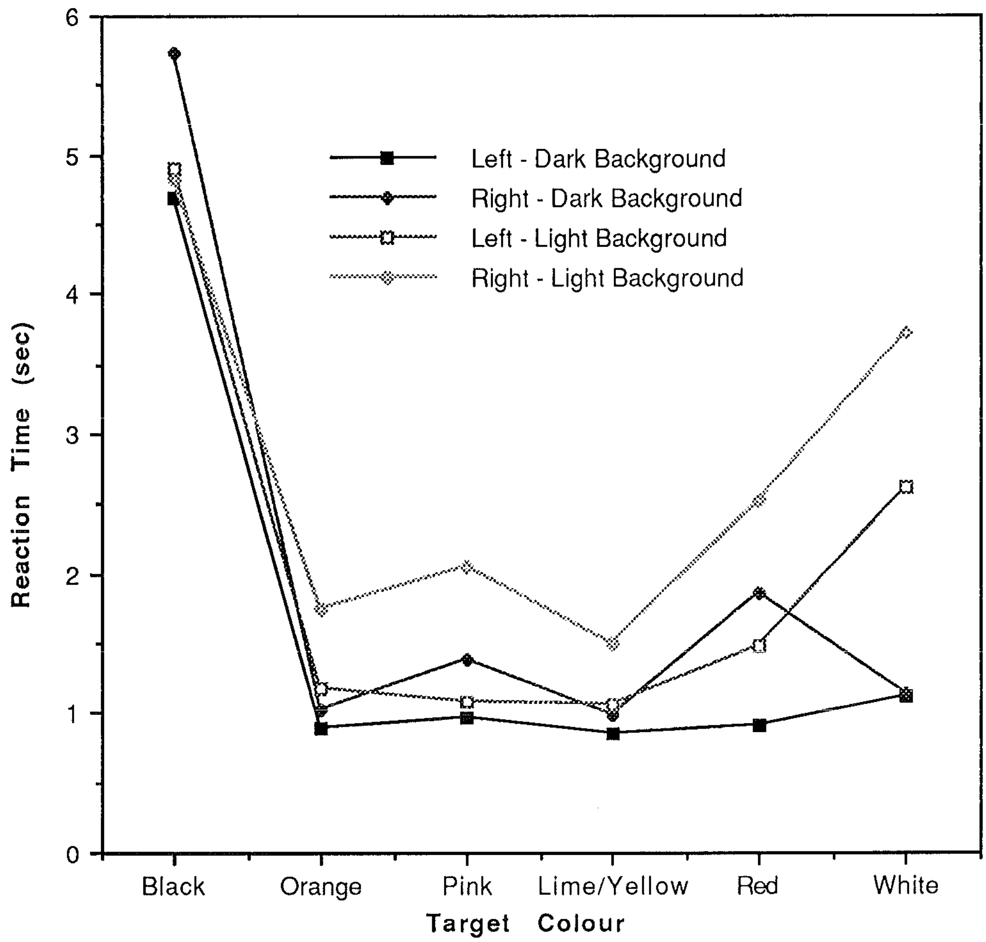

Figure 23. Mean reaction times for the target colour/background lighting/screen position interaction.

detecting this colour in the other three conditions. There were also some interesting results for presentations of the black target colours. Presentations in the left portions of the screen seemed to produce as many problems as those in the right of the screen.

Target colour by background colour by screen position. The third three-way interaction of interest is the target colour, background colour and screen position interaction. Again this interaction was highly significant ($F(30,1170) = 51.6$, $p < .0001$). The results can be seen from Figure 24.

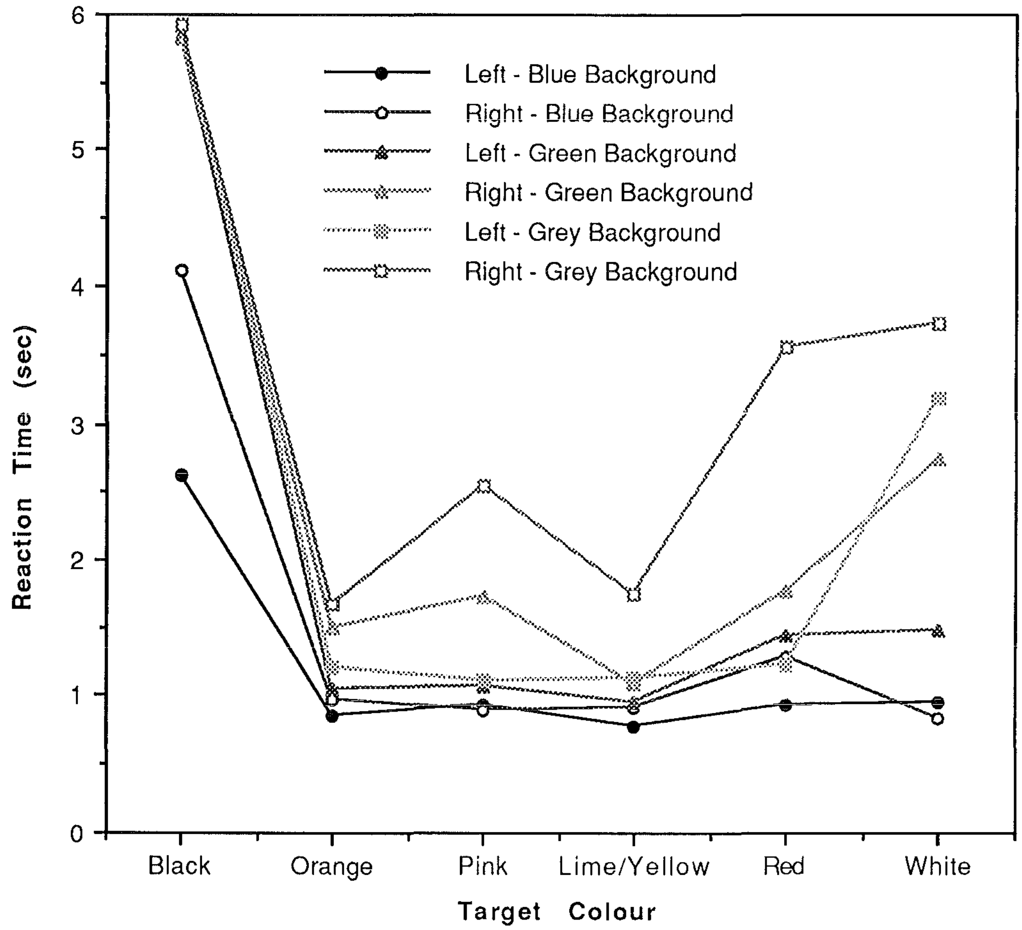

Figure 24. Mean reaction times for the target colour/background colour/screen position interaction.

As we would expect from our earlier results, targets presented against grey backgrounds in the right of the screen presented the greatest problems. These were generally seen much slower than all other background colour/screen position combinations.

There was a large amount of variability for black presentations, with all but the targets presented against the blue background being seen near the 6-second limit of presentation time. Presentations of the pink target were seen far slower than either of the other two fluorescent colours for both grey and green right conditions. Again, fluorescent lime/yellow seems to have the smallest amount of variation of all the target colours. In particular, targets in the right-green conditions seem to be seen much faster than for other target colours.

Background colour by background illumination by screen position. The final three-way interaction, background colour by background illumination by screen position was also examined, not so much for the application of the results to the cycling situation, but rather to help explain the earlier results found for the main effect of screen position.

Again the result of the ANOVA was found to be significant ($F(6,234) = 34.52$, $p < .0001$). The outcome can be seen in Figure 25. It can be seen that the light grey background colour showed an increase in reaction time as the angle from the line of sight increased. Dark grey and dark green also showed similar results. For the light green background, there was a decease in the reaction time as targets moved from the far-left to the mid-left of the presentation screen, but as they moved from here further to the right, there was a subsequent increase in reaction time.

Both blue backgrounds showed mixed results. For the dark blue background, there was a decrease in reaction time as the targets moved from the far-left to the mid-right of the screen, but as they moved from here to the far-right, there was a large increase in reaction times. The light blue showed an increase in reaction times from the far-left to the mid-left of the screen, but then decreased with a move to the mid-right. Finally, there was an increase with a move to the far-right of the screen.

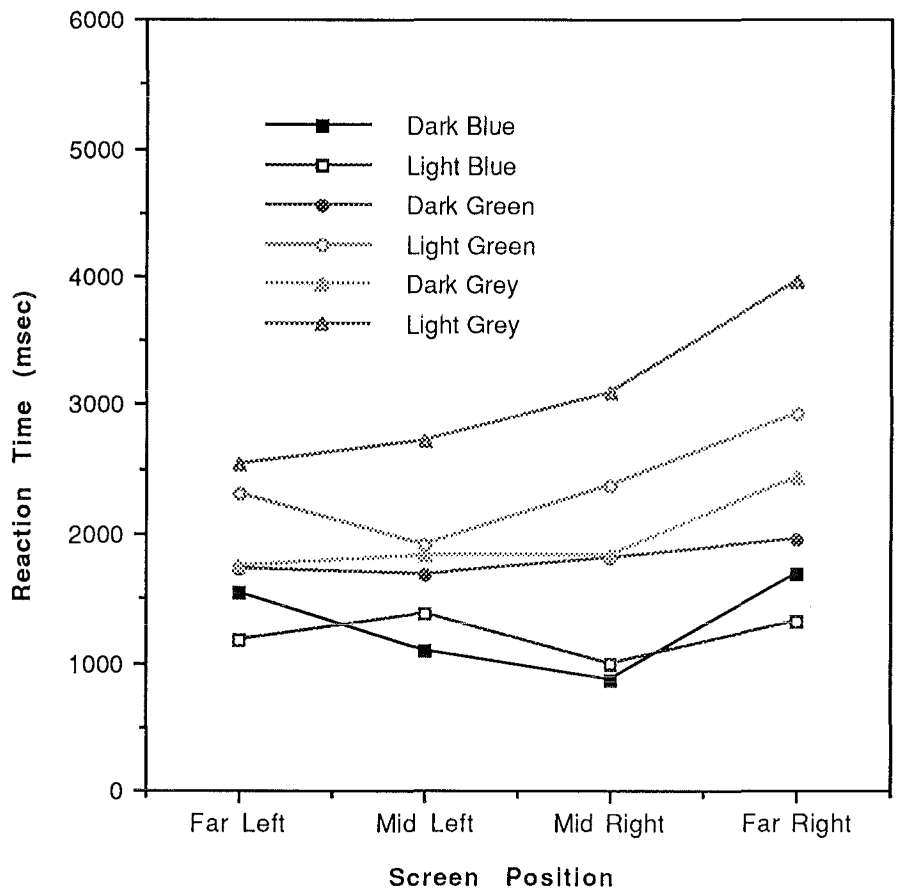

Figure 25. Mean reaction times for the background colour/background lighting/screen position interaction.

The four-way interaction, target colour by background colour by background illumination by screen position also provided a significant result ($F(30,1170) = 28.71$, $p < .0001$). However, due to the large number of means involved (144) it was impossible to graph the results or statistically analyse them. Such an analysis would provide little additional useful information anyway.

DISCUSSION

Every year in New Zealand there are a large number of cyclist deaths and accidents. Some of these are the result of car drivers not seeing the cyclists due to their low conspicuity. It is suggested that if this conspicuity can be increased, there will be fewer such accidents. It was thought that the best way to accomplish this is to use highly visible colours. This experiment examined a number of colours against various background conditions to determine which was the most conspicuous.

Distraction task

The distraction task was designed to prevent the subjects from directly fixating the slide projection screen. This allowed the presentation of targets in the periphery of the visual field, the position that target are most likely to appear. Due to the low error rates in the distraction task and lack of significance in the ANOVA for the within subject variables and distraction task scores, it was concluded that the distraction task had been effective in preventing the subjects from examining the slide presentation screen before each slide was presented. This suggested that each slide was indeed presented in the periphery of the subject' s eye for the vast majority of trials.

Catch trials

The catch trials were used to ensure that subjects were detecting targets before they indicated their presence. As was seen in the results, there were an extremely low number of errors in the presentation of catch trials, meaning that subjects were identifying the presence of a target before indicating so. However, against the dark grey background condition there were a small number of false reports. It was seen in the results section that these were not due to a response bias in this condition, and so must have been caused by some other variable.

Subjects often reported during the experiment that they were unsure whether they had seen a target in this background condition even though they had just responded as though they had. This occurred even though it was stressed to subjects that they should not respond to any slide presentations if they were unsure whether there was a target presented. It is probable that due to the shape of the background texture in this condition, a number of subjects thought that they had seen a target present in this condition when in fact there was none. This was compounded by the fact that it was extremely difficult for subjects to identify targets in this condition (as was seen in the results). It may be that subjects were becoming concerned by this fact, and so were more willing to report the presence of a target when there was none, despite the instructions.

Due to these factors, and because in the other background conditions there was an extremely small number of false reports, it was concluded that the use of catch trials had been successful in obligating subjects to report the presence of a target only once that target had been seen, and that the subjects did not automatically press the response key on the presentation of a slide. Having said this it should also be noted that those reaction times in the dark grey background condition may be shorter than should be the case due to the number of false reports, and that this should be considered in the interpretation of the results.

Main effects and interactions

From the results, it is clear that against all the backgrounds tested, subjects are quicker to detect fluorescent colours. Of these colours, lime/yellow appeared to be the best, followed by orange and then pink. Although there was not much difference between the fluorescent lime/yellow and the orange, the difference between lime/yellow and pink was substantial. Of the non-fluorescent colours, red was detected the quickest, followed by white then black. The differences between the fluorescent and non-fluorescent colours were sizeable, suggesting that colours such as red and white which are usually thought good in the traffic situation should not be used to increase conspicuity. It could be concluded that for cyclists to be most conspicuous, they should wear one of the fluorescent colours, and in particular lime/yellow. These same results were seen for all of the background conditions that the colours were tested against. This result for lime/yellow is in accordance with previous research (e.g., Solomon, 1974), which suggests that the human eye responds best to colours with a wavelength between 505 and 580 millimicrons, an area that includes lime/yellow.

Perhaps of more practical interest than reaction times is the time it takes drivers to begin breaking upon the presentation of these various target colours. Given that the average driving speed of cars in 50 km areas in the Christchurch region is 57.4 km (P. Graham, personal communication, 21 February 1994), it would take a driver 62 metres further driving to spot a target in black than in lime/yellow. For white coloured targets, drivers would travel 15 metres more before detecting a target than they would if that target was fluorescent lime/yellow. Similarly, red targets would take 7 metres longer, pink would take 3 metres, and orange would take 1.5 metres longer to detect.

Of the background colours, targets presented against the blue backgrounds were seen faster than both green and grey, while targets presented against the green were seen faster than those presented against the grey. These results are consistent with research in the area of colour contrast (e.g., Carter & Carter, 1981). This is most evident with black targets presented against the darker coloured backgrounds (green and grey), and with the white targets when presented against the grey backgrounds. The results also lend support to the research on background complexity (e.g., Jenkins & Cole, 1982) which suggests that the more complex the background, the lower the conspicuity of targets. From a subjective observation of the backgrounds, the blue background appeared the least complex, while the grey seemed to be the most.

The findings for background illumination showed that targets presented against dark backgrounds were seen faster than those presented against light coloured backgrounds. These findings are consistent with the literature on luminance contrast (e.g., Jenkins & Cole, 1982) which states that the greater the contrast, the greater the conspicuity. As most of the targets were light coloured they contrasted best with the dark backgrounds. Of particular interest were the results for white target colours. These were detected significantly slower against the light backgrounds, indicating that white is not appropriate for increasing conspicuity against such backgrounds. White is often assumed to be a highly visible colour, but as can be seen here, it should not be adopted in an attempt to increase daytime conspicuity. Surprisingly, there was no difference for the black target colour against the two background illuminations, probably as a result of the difficulty subjects had in detecting this target colour in all situations.

Generally the results for the different screen positions were not as expected. Previous research has found that the further into the periphery that a target is presented, the slower the detection of the target (e.g., Seigel & Federman, 1965; Beith et al., 1982). In this study, targets presented further in the subject's periphery (i.e., the far-right screen position, or 65 deg from the line of sight) were detected significantly slower than those nearer to the fovea (i.e., the far-left to the mid-right screen positions, situated 35, 45 and 55 deg from the line of sight), but there was no real difference in detectability for those targets presented in the far-left to mid-right positions. In fact, those in the mid screen positions were seen the best. This may be due to these positions having brighter back illumination due to the projection unit used. Those portions around the edges of the screen were darker, as light was reflected on the inside of the lens. Another confounding factor may be the actual background photos used. The complexity of each photo was not uniform from left to right. For example in some photos there were more extensive areas of shadowing. This may have made the detection in these parts of the displays much harder, although it is not possible to tell from the results whether this has been the case.

Those targets of low contrast to the background were detected the slowest in the far-right of the periphery (e.g., white on light backgrounds), while those of high contrast were seen relatively well (e.g., lime/yellow against the dark backgrounds). Of particular interest were the presentations of red targets in the far-right position. These were seen poorly when compared to the other three positions that red was presented in. These three positions were seen almost as well as for the fluorescent colours. This finding is in accordance with previous research (e.g., Solomon, 1990). Due to this low peripheral detection and the fact that red is not seen well in dull light, red should not be used in an attempt to increase the conspicuity of objects.

Methodological Issues

Generally the method used in this experiment was quite successful. The distraction task did appear to be cognitively demanding and also resulted in the peripheral presentation of the targets. The catch trials also appeared to be successful in requiring that subjects did see the targets before indicating they were present. There were however a number of methodological problems that need to be addressed if a similar procedure is adopted in future research.

Firstly there were the statistical difficulties in the data analysis that resulted from the large number of targets not seen. Due to the number of targets not seen, the normal distribution that is assumed to underlie the analysis of variance was skewed, with a column at the six second mark (the 'time-out' point where the computer recorded a 'no target spotted'). This may have resulted in a violation of homogeneity principle of the ANOVA. It had been intended that subjects should detect all targets within the 6-sec time limit. The visual angle of the target was made bigger than that used in previous research specifically for this reason. However, due to the backgrounds used in this study there were still a number of targets that were not detected. Future researchers would be best to conduct pilot studies to determine the ideal size of targets for the backgrounds they are using. This is not as easy as it sounds, especially when using a variety of background conditions as in this study. Targets can be made too easy to detect, which would mean that there is less chance of a significant result. This was seen in the present study with the blue background conditions. The best solution may be to make the target size different to suit each background condition. For example, those targets presented against the blue background could have been made smaller to increase the difficulty of target detection.

A common criticism of this type of research is that the colour reproduction of targets is often inadequate. This was especially the case with earlier research in this area. By experimentation in the photographic laboratory it was considered that the colour reproduction in this study was reasonably good. It had been intended that the luminance contrast between the target and the background would be compared with the real-world situation and that found in the slides (as has been mentioned, luminance contrast has been identified as the most important factor in conspicuity). This analysis was unable to be performed as the reflection of light from the slide projection screen was too low to be measured with the available equipment. Beyond this, there also would have been a problem in testing the contrast of the targets on the projection screen due to the small size involved. However, even though objective measures for the accuracy of slide production were unattainable, from a subjective point of view the colour reproduction appeared to be very good.

It should be noted that this analysis examined the search conspicuity and not the attention conspicuity of targets (attention conspicuity refers to the situation where an observer is unprepared for the presentation of a particular target, whereas in search conspicuity they either have been informed of what to look for or can work this out from the experimental design. See the earlier reference to this distinction in the introduction, p16). It was noted earlier that attention conspicuity is the most appropriate type of conspicuity to examine, as in the traffic situation drivers are often not expecting the presence of a cyclist. However, it was assumed in this analysis as it has been in previous research that the order of detection of colours would remain unchanged whether the subject knew what to look for or not (although it is known that search conspicuity is faster than attention conspicuity). This assumption needs to be confirmed with empirical analysis. This could be achieved by showing subjects a large number of distraction slides (e.g., of various shapes and colours), and only presenting the target slides with the same incidence that cyclists are seen in the traffic situation. That way, subjects will be as unprepared for the presentation of the target slide as they would be for the presence of a cyclist in the traffic situation.

A final criticism of the methodology used in this study is that although the background luminance was altered in a controlled way, the luminance of the target colours remained the same. It had been intended to alter the lighting level in the photographic laboratory to match the background luminance. This would have given a more accurate representation of the lighting condition in the real-world (and particularly the luminance contrast). Due to the technology available in the photographic laboratory it was not possible to accurately alter the lighting levels. It is thought that this should be attempted in future research.

A methodology that may be of use in future research could incorporate the use of computer graphics to display target presentations. This method was attempted in the current analysis, but it was found that the technology was not available to store all of the target presentations that were to be used (i.e., 160 frames) in a way that could be randomly accessed at a high speed. It is probable that in the near future, such technology will exist. It was found that the colour reproduction on the computer from the photographs was almost as good as for the slide presentations. The production of fluorescent colours was also very good. By using a computer a greater degree of control can be achieved. For instance, the level of lighting may be changed without any other changes. It may also be possible to analyse the variable of motion, a factor which is not able to be examined when using slide presentations, but one which has been identified as being important in conspicuity (e.g., Solomon, 1974; Reinhardt-Rutland, 1991).

Applications of the Current Research

As already mentioned, the results indicate that the best colour for cyclists to wear in daylight (assuming they will be seen most commonly against the types of backgrounds tested here) is fluorescent lime/yellow. However, these results may also be of use to others who require high conspicuity. This may include school patrols at traffic crossings, horse riders, road workers, emergency workers and pedestrians. Results may also be used outside of the road traffic situation. For example, the results for the green backgrounds may be of use to those wanting to use signage in the forest environment. There are a vast number of possible applications. However, it must be remembered that the background that a colour is tested against must closely approximate the background the target is seen against in the real situation. For example, research into the conspicuity of forest workers has found that fluorescent orange is not a good colour to wear in a pine forest environment. This appears to be contrary to the results found in this analysis. The reason is that when pine trees die, the pine needles take on an orange appearance. Also, the stumps of trees are orange. Orange targets do not show up as they are mistaken for these features (R. Parker, personal communication, 15 February, 1994). That is, there is low colour contrast, so conspicuity is low.

It should be noted that the subject sample used in this experiment had good colour vision. In the general population, 8% of males are colour blind (Michon, et al., 1969). However, previous research has focused on this portion of the population. These studies generally find that luminance contrast is even more important for this group of people. This means that the results from this study are also applicable to those who are colour blind, as the colours identified as being highly conspicuous here offer high luminance contrast.

Some discussion should be made of the way that highly conspicuous colours should be worn. A small literature exists on the comfort levels of those wearing fluorescent garments (Fulton et al., 1980; Stroud et al., 1980; Watts, 1980). These generally find that such garments are uncomfortable when the wearer is active. As user acceptance is essential in an attempt to convert cyclists to the use of highly conspicuous garments, alternative ways to display conspicuous colours may need to be adopted. Fluorescent cycling vests should be encouraged, as the greater the target area the greater the conspicuity. However, it may not be possible to encourage cyclists to wear this equipment. Perhaps one answer is to require cyclists to wear fluorescent helmets. These are in a position so as to be easily seen by other road users, and are now compulsory in New Zealand. Also they are in a position of high reflectance. Watts (1980) using a photometer, found that the head was the brightest position for someone in a cycling position. Light levels were seven times brighter here than at the front of the cyclists jacket. In addition, it has been established (e.g., Vaughan, 1976) that the size of a cycle helmet may be large enough to increase conspicuity if brightly coloured.

It is suggested that cycle helmet colours be regulated to encourage higher conspicuity. It should be noted that cycle helmets will have to conform to one standard from 1997 (Land Transport, 1993) so this would be a good time to make such measures compulsory. For maximum effect it is likely that cyclists should adopt one standard colour for use (preferably fluorescent lime/yellow) as this would make them more identifiable as cyclists. This would change the detection task of the driver from a search conspicuity to an easier attention conspicuity task. However, the benefit that a standard safety colour may have could be reduced if the colour is overused (e.g., in advertising signs). For example, if fluorescent lime/yellow was to be seen in the background often, the colour contrast would be reduced, thereby decreasing the conspicuity of this colour.

Other factors such as the cost of the conspicuous aid and the length of time that such an aid will remain effective before fading also need to be considered. Patel (1990) suggests that one answer could be to provide supermarkets with shopping bags that may be converted into safety vests for cyclists, pedestrians and other road users. Such avenues need further exploration.

Conclusion

It must be remembered that the results and discussion given above are relevant only to the situation where cyclists are seen during the daytime. It is not appropriate to generalise these to cycling in the dark. It has been found that in such a situation that reflecterised garments, and the use of lights are the most effective way to increase conspicuity (e.g., Noordzij, 1976). It is also important to remember that this is an exploratory study. It is assumed that the results are applicable to the real-world situation, but only carefully conducted archival studies (as discussed previously) can provide positive evidence for the applicability of these results.

For those who work against the backgrounds tested in this analysis, use of fluorescent colours such as those tested here are highly recommended. However, it is recognised that this is not the complete answer to reducing conspicuity related accidents. Education that increases the awareness of road users (i.e., observer characteristics of conspicuity) to the presence of other road users are also recommended. Perhaps a good time for such education would be during the drivers license test. It is hoped that the results of this study will be considered by those who need to increase the conspicuity of others in the traffic environment. It is further hoped that they will be of use in reducing the number of accidents and deaths that occur in such situations.

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APPENDICES

Appendix A- Instructions given prior to the experiment

This experiment concerns the location of certain target colours against differing backgrounds. There are six different colours which you will be required to locate in as short a space of time as is possible. The target colours are small squares which may be located in any part of the slide. Here are some examples: [subjects were then shown an example of each of the target colours].

Upon the detection of one of these targets you will be required to press this response key on the mouse as fast as possible. Your response time will be recorded, so try to find the target and press the key as quickly as you can.

Along with these six different target colours, there are also six different backgrounds [subjects were then shown each of the six different backgrounds]. Make sure that when you identify a target that this target is actually a square, and not merely a part of the background [subjects were then shown parts of different slides that might be easily confused with target colours, such as bright yellow leaves in the green background]. If you are in any doubt as to whether it is a target you have spotted, please do not press the response key.

Please note that in some of the slide presentations there will be no targets to find. If this is the case then you are not required to press the response key, but rather wait until the next slide is presented [examples were then given of slides with no target presentation]. There are a lot of these presentations, so don't be too concerned if you can't spot a target.

Prior to each presentation of a slide, you will be required to engage in a distraction task. This task will be performed for a randomly determined period of between 3 and 7 seconds. During this task you will be required to keep the cursor inside the constantly changing boundary, much the same as the task of keeping a car on the road. If you stray from this boundary, the computer will let you know by emitting a tone, and it is your task to return to within the boundary as soon as possible. Your performance in this task will be recorded by the computer, so try to be as accurate as possible. You may now practice this distraction task. [Subjects were allowed to practice the distraction task until they were capable of performing it competently.]

In total this cycle of distraction task-slide presentation will be repeated 160 times and the experiment will take around 30 minutes to complete. As you carry out the task, the slide number that you are up to will be displayed in the top right hand corner of the computer screen to inform you of your progress.

Before we begin, I must stress that participation in this experiment is entirely voluntary, and if you wish not to continue at any stage then the experiment will be terminated. Also, all results obtained from individuals will be treated as confidential. Do you have any questions before we begin?

Appendix B - ANOVA summary table for reaction time

Source of Variation	df	Sum of Squares	Mean Square	F	p
Subjects	39	65277108.638	1673772.016		
Background Colour	2	1575753797.059	787876898.529	1542.016	.0000
Error	78	39853295.600	510939.687		
Background Light	1	414718390.809	414718390.809	780.330	.0000
Error	39	20727139.486	531465.115		
BCol x BLight	2	342588046.186	171294023.093	401.306	.0000
Error	78	33293596.924	426840.986		
Target Colour	5	10699170230.154	2139834046.031	3956.102	.0000
Error	195	105474446.368	540894.597		
BCol x TCol	10	1344422989.294	134442298.929	256.851	.0000
Error	390	204135904.665	523425.397		
BLight x TCol	5	489765663.708	97953132.742	269.471	.0000
Error	195	70882780.061	363501.436		
BCol x BLight x TCol	10	526212630.317	52621263.032	163.671	.0000
Error	390	125387367.210	321506.070		
Screen Position	3	345953422.986	115317807.662	268.951	.0000
Error	117	50165874.825	428768.161		
BCol x Pos	6	153228906.611	25538151.102	78.857	.0000
Error	234	75781757.993	323853.667		
BLight x Pos	3	31232298.721	10410766.240	22.498	.0000
Error	117	54139691.154	462732.403		
BCol x BLi x Pos	6	84951885.085	14158647.514	34.527	.0000
Error	234	95956185.847	410069.170		
TCol x Pos	15	214365167.056	14291011.137	38.350	.0000
Error	585	217997250.761	372644.873		
BCol x TCol x Pos	30	521645770.421	17388192.347	51.570	.0000
Error	1170	394493757.134	337174.151		
BLi x TCol x Pos	15	227277084.709	15151805.647	43.940	.0000
Error	585	201723551.277	344826.583		
BCol x BLi x TCol x P	30	296117965.286	9870598.843	28.712	.0000
Error	1170	402228847.742	343785.340		

Appendix C - Tukey hsd summary tables.

Target Colour

Upper Triangle: .05 level; Lower Triangle: .01 level

	A	B	C	D	E	F
A. Lime/Yellow	X	-	s	s	s	s
B. Orange	-	X	-	s	s	s
C. Pink	s	-	X	s	s	s
D. Red	s	s	s	X	s	s
E. White	s	s	s	s	X	s
F. Black	s	s	s	s	s	X

Background Colour

Upper Triangle: .05 level; Lower Triangle: .01 level

	A	B	C
A. Blue	X	s	s
B. Green	s	X	s
C. Grey	s	s	X

Background Illumination

Upper Triangle: .05 level; Lower Triangle: .01 level

	A	B
A. Dark	X	s
B. Light	s	X

Screen Position

Upper Triangle: .05 level; Lower Triangle: .01 level

	A	B	C	D
A. Mid Left	X	-	s	s
B. Mid Right	-	X	-	s
C. Far Left	-	-	X	s
D. Far Right	s	s	s	X

Target Colour by Background Colour

Upper Triangle: .05 level; Lower Triangle: .01 level

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
A. Blue L/Y	X	-	-	-	-	s	s	s	s	s	s	s	s	s	s	s	s	s
B. Blue Oran	-	X	-	-	-	-	s	s	s	s	s	s	s	s	s	s	s	s
C. Blue Pink	-	-	X	-	-	-	s	s	s	s	s	s	s	s	s	s	s	s
D. Blue Whi	-	-	-	X	-	-	s	s	s	s	s	s	s	s	s	s	s	s
E. Gree L/Y	-	-	-	-	X	-	-	s	s	s	s	s	s	s	s	s	s	s
F. Blue Red	-	-	-	-	-	X	-	s	s	s	s	s	s	s	s	s	s	s
G. Gree Oran	s	s	s	s	-	-	X	-	-	-	s	s	s	s	s	s	s	s
H. Gree Pink	s	s	s	s	s	-	-	X	-	-	s	s	s	s	s	s	s	s
I. Grey L/Y	s	s	s	s	s	s	-	-	X	-	-	s	s	s	s	s	s	s
J. Grey Oran	s	s	s	s	s	s	-	-	-	X	-	-	s	s	s	s	s	s
K. Grey Pink	s	s	s	s	s	s	s	-	-	-	X	-	s	s	s	s	s	s
L. Gree Red	s	s	s	s	s	s	s	s	s	-	-	X	s	s	s	s	s	s
M. Gree Whit	s	s	s	s	s	s	s	s	s	s	s	s	X	-	s	s	s	s
N. Grey Red	s	s	s	s	s	s	s	s	s	s	s	s	-	X	s	s	s	s
O. Blue Blac	s	s	s	s	s	s	s	s	s	s	s	s	s	s	X	s	s	s
P. Grey Whit	s	s	s	s	s	s	s	s	s	s	s	s	s	s	s	X	s	s
Q. Gree Black	s	s	s	s	s	s	s	s	s	s	s	s	s	s	s	s	X	-
R. Grey Black	s	s	s	s	s	s	s	s	s	s	s	s	s	s	s	s	-	X

Target Colour by Background Illumination

Upper Triangle: .05 level; Lower Triangle: .01 level

	A	B	C	D	E	F	G	H	I	J	K	L
A. Dark L/Y	X	-	s	s	s	s	s	s	s	s	s	s
B. Dark Orang	-	X	s	s	s	s	s	s	s	s	s	s
C. Dark Pink	s	-	X	-	-	-	s	s	s	s	s	s
D. Dark White	s	s	-	X	-	-	s	s	s	s	s	s
E. Dark Red	s	s	-	-	X	-	s	s	s	s	s	s
F. Light L/Y	s	s	-	-	-	X	s	s	s	s	s	s
G. Light Oran	s	s	s	s	s	s	X	-	s	s	s	s
H. Light Pink	s	s	s	s	s	s	-	X	s	s	s	s
I. Light Red	s	s	s	s	s	s	s	s	X	s	s	s
J. Light Whit	s	s	s	s	s	s	s	s	s	X	s	s
K. Light Black	s	s	s	s	s	s	s	s	s	s	X	-
L. Dark Black	s	s	s	s	s	s	s	s	s	s	-	X

Background Colour by Background Illumination

Upper Triangle: .05 level; Lower Triangle: .01 level

	A	B	C	D	E	F
A. Blue Light	X	-	s	s	s	s
B. Blue Dark	-	X	s	s	s	s
C. Gree Dark	s	s	X	s	s	s
D. Grey Dark	s	s	s	X	s	s
E. Gree Light	s	s	s	s	X	s
F. Grey Light	s	s	s	s	s	X